Common Conversion Factors

IMPERIAL to METRIC

TO CONVERT	INTO	MULTIPLY BY
Acres	Hectares	0.4047
Cubic Feet	Cubic Metres	0.0283
Cubic Inches	Cubic Centimetres	16.3871
Degrees Fahrenheit	Degrees Celsius	-32 x 5 ÷ 9
Feet	Metres	0.3048
Fluid Ounces	Millilitres	28.4130
Gallons	Litres	4.5460
Horse Power (Electric)	Kilowatts	0.7460
Inches	Millimetres	25.4000
Miles	Kilometres	1.6093
PSI	Bar	0.0689
Pounds	Kilograms	0.4536
Square Feet	Square Metres	0.0929
Square Miles	Square Kilometres	2.5899
Yards	Metres	0.9144

METRIC to IMPERIAL

TO CONVERT	INTO	MULTIPLY BY
Bar	PSI	14.5038
Cubic Centimetres	Cubic Inches	0.0610
Degrees Celsius	Degrees Fahrenheit	x 9 ÷ 5 + 32
Grams	Ounces	0.0353
Hectares	Acres	2.4710
Kilograms	Pounds	2.2046
Kilometres	Miles	0.6214
Kilowatts	Horse Power (Electric)	1.3405
Litres	Gallons	0.2200
Metres	Feet	3.2808
Metres	Yards	1.0936
Millimetres	Inches	0.0394
Square Centimetres	Square Inches	0.1550
Square Metres	Square Feet	10.7639
Square Millimetres	Square Inches	0.0015

For detailed Conversion Factors, refer pages 4 & 5

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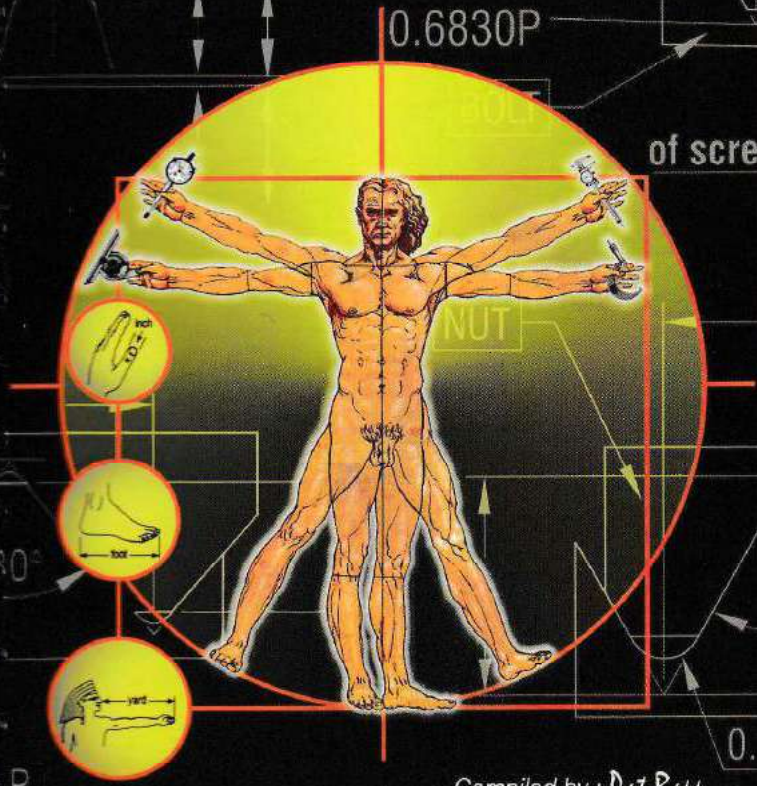
ENGINEERS Black Book

2ND EDITION

Data Sheets ■ Formulae
Reference Tables ■ Equivalent Charts



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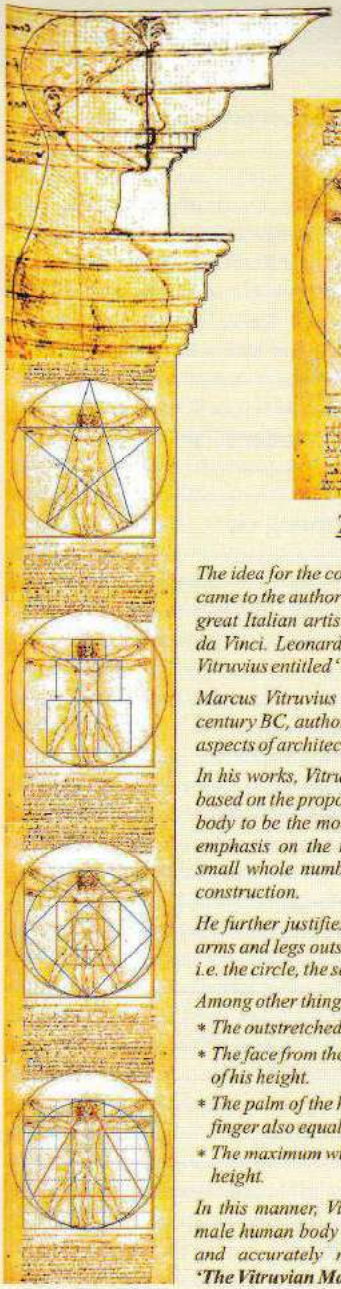

About the Cover

The Vitruvian Man

The idea for the cover design of the ***'Engineers Black Book'*** *came to the author from a sketch of the 'Vitruvian Man' by the great Italian artist, inventor and mathematician, Leonardo da Vinci. Leonardo drew his inspiration from the works of Vitruvius entitled* 'De Architectura'.

Marcus Vitruvius was a Roman architect who in the first century BC, authored a series of 10 books, each dealing with aspects of architecture, city planning & machines.

In his works, Vitruvius emphasises that 'building' should be based on the proportions of man, as he considered the human body to be the model of perfection. This is borne out by his emphasis on the rationalisation of geometry by means of small whole numbers joined together to arrive at the final construction.

He further justifies this by stating that the human body with arms and legs outstretched, fits into perfect geometric forms, i.e. the circle, the square and the triangle.

Among other things, he notes that:

* *The outstretched length of a man's hands equals his height.*
* *The face from the chin to the top of the forehead equals 10% of his height.*
* *The palm of the hand from the wrist to the top of the middle finger also equals 10% of his height.*
* *The maximum width of a man's shoulders equals 25% of his height.*

In this manner, Vitruvius delineates the proportions of the male human body that Leonardo da Vinci later so faithfully and accurately reproduced in his now famous sketch ***'The Vitruvian Man'.***

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Drill Point Sharpening Gauge on Inside Back Cover

CONVERSION FACTORS (APPROXIMATE)
IMPERIAL TO METRIC

TO CONVERT	INTO	MULTIPLY BY
Acres	Hectares	0.4047
Atmospheres	Kilopascals	101.3250
British Thermal Units	Kilojoules	1.0551
Bushels	Cubic Metres	0.0364
Cubic Feet per Minute	Litres per Second	0.4719
Cubic Feet	Cubic Metres	0.0283
Cubic Inches	Cubic Centimetres	16.3871
Cubic Inches	Fluid Ounces	0.5767
Cubic Inches	Litres	0.0164
Cubic Yards	Cubic Metres	0.7646
Cycles per Second	Hertz	1.0000
Degrees Fahrenheit	Degrees Celsius	-32 x 5 ÷ 9
Feet per Second	Miles per Hour	0.6819
Feet	Metres	0.3048
Fluid Ounces	Cubic Inches	1.7339
Fluid Ounces	Millilitres	28.4130
Fluid Ounces	Litres	0.0284
Foot Pound	Newton-metre	1.3558
Furlongs	Metres	201.0000
Furlongs	Kilometres	0.2010
Gallons per Minute	Litres per Second	0.0758
Gallons per Hour	Litres per Second	0.0013
Gallons	Litres	4.5460
Grains	Grams	0.0648
Horse Power (Electric)	Kilowatts	0.7460
Hundredweights	Kilograms	50.8032
Inches of Mercury	Millibars	33.7410
Inches	Millimetres	25.4000
Inches	Centimetres	2.5400
Kilowatt Hours	Megajoules	3.6000
Miles per Hour	Feet per Second	1.4667
Miles per Hour	Kilometres per Hour	1.6093
Miles	Kilometres	1.6093
Miles	Nautical Miles	0.8690
Ounces, Avoirdupois	Grams	28.3495
Pints	Litres	0.5683
Pounds-Force	Newtons	4.4482
Pounds per Square Inch	Bar	0.0689
Pounds per Square Inch	Kilopascals	6.8948
Pounds per Square Inch	Megapascals	0.0069
Pounds	Grams	453.5920
Pounds	Kilograms	0.4536
Square Inches	Square Millimetres	645.1612
Square Inches	Square Centimetres	6.4516
Square Feet	Square Centimetres	929.0310
Square Feet	Square Metres	0.0929
Square Yards	Square Metres	0.8361
Square Miles	Square Kilometres	2.5899
Ton-Force	Kilonewtons	9.9640
Tons-Long (2,240 pounds)	Tonnes	1.0161
Tons-Short (2,000 pounds)	Tonnes	0.9072
Tons per Square Inch	Megapascals	15.4000
Yards	Metres	0.9144
Yards	Kilometres	0.0009

Engineers Black Book - 2nd Edition

CONVERSION FACTORS (APPROXIMATE)
METRIC TO IMPERIAL

TO CONVERT	INTO	MULTIPLY BY
Bar	Pounds per Square Inch	14.5038
Centimetres	Inches	0.3937
Cubic Centimetres	Cubic Inches	0.0610
Cubic Metres	Bushels	27.4962
Cubic Metres	Cubic Feet	35.3147
Cubic Metres	Cubic Yards	1.3079
Degrees Celsius	Degrees Fahrenheit	x 9 ÷ 5 + 32
Grams	Ounces	0.0353
Grams	Grains	15.4324
Grams	Ounces, Avoirdupois	0.0353
Grams	Pounds	0.0022
Hectares	Acres	2.4710
Hertz	Cycles per Second	1.0000
Kilograms	Hundredweights	0.0197
Kilograms	Pounds	2.2046
Kilogram Force	Newton	9.8066
Kilometres per Hour	Miles per Hour	0.6214
Kilometres	Yards	1093.6132
Kilometres	Furlongs	4.9750
Kilometres	Miles	0.6214
Kilopascals	Pounds per Square Inch	0.1450
Kilopascals	Atmospheres	0.0099
Kilojoules	British Thermal Units	0.9478
Kilonewtons	Ton-Force	0.1004
Kilowatts	Horse Power (Electric)	1.3410
Litres per Second	Cubic Feet per Minute	2.1190
Litres per Second	Gallons per Minute	13.1980
Litres per Second	Gallons per Hour	791.8900
Litres	Cubic Inches	60.9362
Litres	Fluid Ounces	35.2113
Litres	Pints	1.7598
Litres	Gallons	0.2200
Megajoules	Kilowatt Hours	0.2778
Megapascals	Pounds per Square Inch	145.0389
Megapascals	Tons per Square Inch	0.0649
Metres	Feet	3.2808
Metres	Furlong	0.0050
Metres	Yards	1.0936
Millibars	Inches of Mercury	0.0296
Millilitres	Fluid Ounces	0.0352
Millimetres	Inches	0.0394
Nautical Miles	Miles	1.1508
Newtons	Pounds-Force	0.2248
Newton	Kilogram-Force	0.1020
Newton-metre	Foot Pound	0.7376
Square Centimetres	Square Inches	0.1550
Square Centimetres	Square Feet	0.0011
Square Metres	Square Feet	10.7639
Square Metres	Square Yards	1.1959
Square Millimetres	Square Inches	0.0015
Square Kilometres	Square Miles	0.3861
Tonnes	Long Tons (2,240 pounds)	0.9842
Tonnes	Short Tons (2,000 pounds)	1.1020

DRILL SIZE & DECIMAL EQUIVALENT CHART

Fract.	(inch)	(mm)	Gauge
	.0039	.10	
	.0059	.150	97
	.0063	.160	96
	.0067	.170	95
	.0071	.180	94
	.0075	.190	93
1/128	.0078	.198	
	.0079	.20	92
	.0083	.210	91
	.0087	.220	90
	.0091	.230	89
	.0094	.240	88
	.0098	.250	
	.0100	.254	87
	.0102	.260	
	.0106	.270	86
	.0110	.280	85
	.0114	.290	84
	.0118	.30	
	.0120	.305	83
	.0122	.310	
	.0125	.317	82
	.0126	.320	
	.0130	.330	81
	.0134	.340	
	.0135	.343	80
	.0138	.350	
	.0142	.360	
	.0145	.368	79
	.0146	.370	
	.0150	.380	
	.0154	.390	
1/64	.0156	.397	
	.0157	.40	
	.0160	.406	78
	.0161	.410	
	.0165	.420	
	.0169	.430	
	.0173	.440	
	.0177	.450	
	.0180	.457	77
	.0181	.460	
	.0185	.470	
	.0189	.480	
	.0193	.490	
	.0197	.50	
	.0200	.508	76
	.0201	.510	
	.0205	.520	
	.0209	.530	
	.0210	.533	75
	.0213	.540	
	.0217	.550	
	.0220	.560	
	.0224	.570	
	.0225	.572	74
	.0228	.580	
	.0232	.590	
	.0236	.60	
	.0240	.610	73
	.0244	.620	
	.0248	.630	
	.0250	.635	72
	.0252	.640	
	.0256	.650	
	.0260	.660	71
	.0264	.670	
	.0268	.680	
	.0272	.690	
	.0276	.70	
	.0279	.710	
	.0280	.711	70
	.0283	.720	
	.0287	.730	
	.0291	.740	
	.0292	.742	69
	.0295	.750	
	.0299	.760	
	.0303	.770	
	.0307	.780	
	.0310	.787	68
	.0311	.790	
1/32	.0313	.794	
	.0315	.80	
	.0319	.810	
	.0320	.813	67
	.0323	.820	
	.0327	.830	
	.0330	.838	66
	.0331	.840	
	.0335	.850	
	.0339	.860	
	.0343	.870	
	.0346	.880	
	.0350	.889	65
	.0350	.890	
	.0354	.90	
	.0358	.910	
	.0360	.914	64
	.0362	.920	
	.0366	.930	
	.0370	.940	63
	.0374	.950	
	.0378	.960	
	.0380	.965	62
	.0382	.970	
	.0386	.980	
	.0390	.990	
	.0390	.991	61
	.0394	1.00	
	.0400	1.016	60
	.0410	1.041	59
	.0413	1.050	
	.0420	1.067	58
	.0430	1.092	57
	.0433	1.100	
	.0453	1.150	
	.0465	1.181	56
3/64	.0469	1.191	
	.0472	1.200	
	.0492	1.250	
	.0512	1.300	
	.0520	1.321	55
	.0531	1.350	
	.0550	1.397	54
	.0551	1.400	
	.0571	1.450	
	.0591	1.500	
	.0595	1.511	53
	.0610	1.550	
1/16	.0625	1.588	
	.0630	1.600	
	.0635	1.613	52
	.0650	1.650	
	.0669	1.700	
	.0670	1.702	51
	.0689	1.750	
	.0700	1.778	50
	.0709	1.800	
	.0728	1.850	
	.0730	1.854	49
	.0748	1.900	
	.0760	1.930	48
	.0768	1.950	
5/64	.0781	1.984	
	.0785	1.994	47
	.0787	2.00	
	.0807	2.050	
	.0810	2.057	46
	.0820	2.083	45
	.0827	2.100	
	.0846	2.150	
	.0860	2.184	44
	.0866	2.200	
	.0886	2.250	
	.0890	2.261	43
	.0906	2.300	
	.0925	2.350	
	.0935	2.375	42
3/32	.0937	2.381	
	.0945	2.400	
	.0960	2.438	41
	.0965	2.450	
	.0980	2.489	40
	.0984	2.500	
	.0995	2.527	39
	.1004	2.550	
	.1015	2.578	38
	.1024	2.600	
	.1040	2.642	37
	.1043	2.650	

DRILL SIZE & DECIMAL EQUIVALENT CHART

Fract.	(inch)	(mm)	Gauge
	.1063	2.700	
	.1065	2.705	36
	.1083	2.750	
7/64	.1094	2.778	
	.1100	2.794	35
	.1102	2.800	
	.1110	2.819	34
	.1122	2.850	
	.1130	2.870	33
	.1142	2.900	
	.1160	2.946	32
	.1161	2.950	
	.1181	3.00	
	.1200	3.048	31
	.1220	3.100	
1/8	.1250	3.175	
	.1260	3.200	
	.1285	3.264	30
	.1299	3.300	
	.1339	3.400	
	.1360	3.454	29
	.1378	3.500	
	.1405	3.569	28
9/64	.1406	3.572	
	.1417	3.600	
	.1440	3.658	27
	.1457	3.700	
	.1470	3.734	26
	.1495	3.797	25
	.1496	3.800	
	.1520	3.861	24
	.1535	3.900	
	.1540	3.912	23
5/32	.1563	3.969	
	.1570	3.988	22
	.1575	4.00	
	.1590	4.039	21
	.1610	4.089	20
	.1614	4.100	
	.1654	4.200	
	.1660	4.216	19
	.1693	4.300	
	.1695	4.305	18
11/64	.1719	4.366	
	.1730	4.394	17
	.1732	4.400	
	.1770	4.496	16
	.1772	4.500	
	.1800	4.572	15
	.1811	4.600	
	.1820	4.623	14
	.1850	4.700	13
3/16	.1875	4.762	
	.1890	4.800	12
	.1910	4.851	11
	.1929	4.900	
	.1935	4.915	10
	.1960	4.978	9
	.1969	5.00	
	.1990	5.055	8
	.2008	5.100	
	.2010	5.105	7
13/64	.2031	5.159	
	.2040	5.182	6
	.2047	5.200	
	.2055	5.220	5
	.2087	5.300	
	.2090	5.309	4
	.2126	5.400	
	.2130	5.410	3
	.2165	5.500	
7/32	.2187	5.556	
	.2205	5.600	
	.2210	5.613	2
	.2244	5.700	
	.2280	5.791	1
	.2283	5.800	
	.2323	5.900	
	.2340	5.944	A
15/64	.2344	5.953	
	.2362	6.00	
	.2380	6.045	B
	.2402	6.100	
	.2420	6.147	C
	.2441	6.200	
	.2460	6.248	D
	.2480	6.300	
1/4	.2500	6.350	E
	.2520	6.400	
	.2559	6.500	
	.2570	6.528	F
	.2598	6.600	
	.2610	6.629	G
	.2638	6.700	
17/64	.2656	6.747	
	.2660	6.756	H
	.2677	6.800	
	.2717	6.900	
	.2720	6.909	I
	.2756	7.00	
	.2770	7.036	J
	.2795	7.100	
	.2810	7.137	K
9/32	.2813	7.144	
	.2835	7.200	
	.2874	7.300	
	.2900	7.366	L
	.2913	7.400	
	.2950	7.493	M
	.2953	7.500	
19/64	.2969	7.541	
	.2992	7.600	
	.3020	7.671	N
	.3031	7.700	
	.3071	7.800	
	.3110	7.900	
5/16	.3125	7.938	
	.3150	8.00	
	.3160	8.026	O
	.3189	8.100	
	.3228	8.200	
	.3230	8.204	P
	.3268	8.300	
21/64	.3281	8.334	
	.3307	8.400	
	.3320	8.433	Q
	.3346	8.500	
	.3386	8.600	
	.3390	8.611	R
	.3425	8.700	
11/32	.3437	8.731	
	.3465	8.800	
	.3480	8.839	S
	.3504	8.900	
	.3543	9.00	
	.3580	9.093	T
	.3583	9.100	
23/64	.3594	9.128	
	.3622	9.200	
	.3661	9.300	
	.3680	9.347	U
	.3701	9.400	
	.3740	9.500	
3/8	.3750	9.525	
	.3770	9.576	V
	.3780	9.600	
	.3819	9.700	
	.3858	9.800	
	.3860	9.804	W
	.3898	9.900	
25/64	.3906	9.922	
	.3937	10.00	
	.3970	10.084	X
	.3976	10.100	
	.4016	10.200	
	.4040	10.262	Y
	.4055	10.300	
13/32	.4063	10.319	
	.4094	10.400	
	.4130	10.490	Z
	.4134	10.500	
	.4173	10.600	
	.4213	10.700	
27/64	.4219	10.716	
	.4252	10.800	
	.4291	10.900	
	.4331	11.00	
	.4370	11.100	
7/16	.4375	11.112	
	.4409	11.200	
	.4449	11.300	

DRILL SIZE & DECIMAL EQUIVALENT CHART

Fraction	(inch)	(mm)	Fraction	(inch)	(mm)	Fraction	(inch)	(mm)
	.4488	11.400	45/64	.7031	17.859	1 3/64	1.0469	26.591
	.4528	11.500		.7087	**18.00**		1.0531	26.750
29/64	.4531	11.509		.7185	18.250	1 1/16	1.0625	26.988
	.4567	11.600	23/32	.7187	18.256		1.0630	**27.00**
	.4606	11.700		.7283	18.500		1.0728	27.250
	.4646	11.800	47/64	.7344	18.653	1 5/64	1.0781	27.384
	.4685	11.900		.7382	18.750		1.0827	27.500
15/32	.4687	11.906		.7480	**19.00**		1.0925	27.750
	.4724	**12.00**	**3/4**	.7500	19.050	1 3/32	1.0937	27.781
	.4764	12.100		.7579	19.250		1.1024	**28.00**
	.4803	12.200	49/64	.7656	19.447	1 7/64	1.1094	28.178
	.4843	12.300		.7677	19.500		1.1122	28.250
31/64	.4844	12.303		.7776	19.750		1.1220	28.500
	.4882	12.400	25/32	.7813	19.844	**1 1/8**	1.1250	28.575
	.4921	12.500		.7874	**20.00**		1.1319	28.750
	.4961	12.600	51/64	.7969	20.241	1 9/64	1.1406	28.972
1/2	.5000	12.700		.7972	20.250		1.1417	**29.00**
	.5039	12.800		.8071	20.500		1.1516	29.250
	.5079	12.900	**13/16**	.8125	20.638	1 5/32	1.1563	29.369
	.5118	**13.00**		.8169	20.750		1.1614	29.500
33/64	.5156	13.097		.8268	**21.00**		1.1713	29.750
	.5157	13.100	53/64	.8281	21.034	1 11/64	1.1719	29.766
	.5197	13.200		.8366	21.250		1.1811	**30.00**
	.5236	13.300	27/32	.8437	21.431	1 3/16	1.1875	30.162
	.5276	13.400		.8465	21.500		1.1909	30.250
17/32	.5313	13.494		.8563	21.750		1.2008	30.500
	.5315	13.500	55/64	.8594	21.828	1 13/64	1.2031	30.559
	.5354	13.600		.8661	**22.00**		1.2106	30.750
	.5394	13.700	**7/8**	.8750	22.225	1 7/32	1.2187	30.956
	.5433	13.800		.8760	22.250		1.2205	**31.00**
35/64	.5469	13.891		.8858	22.500		1.2303	31.250
	.5472	13.900	57/64	.8906	22.622	1 15/64	1.2344	31.353
	.5512	**14.00**		.8957	22.750		1.2402	31.500
	.5610	14.250		.9055	**23.00**	**1 1/4**	1.2500	31.750
9/16	.5625	14.288	29/32	.9063	23.019		1.2598	**32.00**
	.5709	14.500		.9154	23.250	1 17/64	1.2656	32.147
37/64	.5781	14.684	59/64	.9219	23.416		1.2795	32.500
	.5807	14.750		.9252	23.500	1 9/32	1.2813	32.544
	.5906	**15.00**		.9350	23.750	1 19/64	1.2969	32.941
19/32	.5937	15.081	**15/16**	.9375	23.812		1.2992	**33.00**
	.6004	15.250		.9449	**24.00**	1 5/16	1.3125	33.338
39/64	.6094	15.478	61/64	.9531	24.209		1.3189	33.500
	.6102	15.500		.9547	24.250	1 21/64	1.3281	33.734
	.6201	15.750		.9646	24.500		1.3386	**34.00**
5/8	.6250	15.875	31/32	.9687	24.606	1 11/32	1.3437	34.131
	.6299	**16.00**		.9744	24.750		1.3583	34.500
	.6398	16.250		.9843	**25.00**	1 23/64	1.3594	34.528
41/64	.6406	16.272	63/64	.9844	25.003	**1 3/8**	1.3750	34.925
	.6496	16.500		.9941	25.250		1.3780	**35.00**
21/32	.6563	16.669	**1**	1.0000	25.400	1 25/64	1.3906	35.322
	.6594	16.750		1.0039	25.500		1.3976	35.500
	.6693	**17.00**		1.0138	25.750	1 13/32	1.4063	35.719
43/64	.6719	17.066	1 1/64	1.0156	25.797		1.4173	**36.00**
	.6791	17.250		1.0236	**26.00**	1 27/64	1.4219	36.116
11/16	.6875	17.462	1 1/32	1.0313	26.194		1.4370	36.500
	.6890	17.500		1.0335	26.250	1 7/16	1.4375	36.512
	.6988	17.750		1.0433	26.500	1 29/64	1.4531	36.909

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DRILL SIZE & DECIMAL EQUIVALENT CHART

Fraction	(inch)	(mm)	Fraction	(inch)	(mm)	Fraction	(inch)	(mm)
	1.4567	**37.00**	1 31/32	1.9687	50.006	2 31/32	2.9687	75.406
1 15/32	1.4687	37.306	1 63/64	1.9844	50.403		2.9921	**76.00**
	1.4764	37.500		1.9882	50.500	**3**	3.0000	76.200
1 31/64	1.4844	37.703	**2**	2.0000	50.800	3 1/32	3.0313	76.994
	1.4961	**38.00**		2.0079	**51.00**		3.0315	**77.00**
1 1/2	1.5000	38.100	2 1/32	2.0313	51.594	3 1/16	3.0625	77.788
1 33/64	1.5156	38.497		2.0472	**52.00**		3.0709	**78.00**
	1.5157	38.500	2 1/16	2.0625	52.388	3 3/32	3.0937	78.581
1 17/32	1.5313	38.894		2.0866	**53.00**		3.1102	**79.00**
	1.5354	**39.00**	2 3/32	2.0937	53.181	3 1/8	3.1250	79.375
1 35/64	1.5469	39.291	2 1/8	2.1250	53.975		3.1496	**80.00**
	1.5551	39.500		2.1260	**54.00**	3 5/32	3.1563	80.169
1 9/16	1.5625	39.688	2 5/32	2.1563	54.769	3 3/16	3.1875	80.962
	1.5748	**40.00**		2.1654	**55.00**		3.1890	**81.00**
1 37/64	1.5781	40.084	2 3/16	2.1875	55.562	3 7/32	3.2187	81.756
1 19/32	1.5937	40.481		2.2047	**56.00**		3.2283	**82.00**
	1.5945	40.500	2 7/32	2.2187	56.356	**3 1/4**	3.2500	82.550
1 39/64	1.6094	40.878		2.2441	**57.00**		3.2677	**83.00**
	1.6142	**41.00**	**2 1/4**	2.2500	57.150	3 9/32	3.2813	83.344
1 5/8	1.6250	41.275	2 9/32	2.2813	57.944		3.3071	**84.00**
	1.6339	41.500		2.2835	**58.00**	3 5/16	3.3125	84.138
1 41/64	1.6406	41.672	2 5/16	2.3125	58.738	3 11/32	3.3437	84.931
	1.6535	**42.00**		2.3228	**59.00**		3.3465	**85.00**
1 21/32	1.6563	42.069	2 11/32	2.3437	59.531	3 3/8	3.3750	85.725
1 43/64	1.6719	42.466		2.3622	**60.00**		3.3858	**86.00**
	1.6732	42.500	2 3/8	2.3750	60.325	3 13/32	3.4063	86.519
1 11/16	1.6875	42.862		2.4016	**61.00**		3.4252	**87.00**
	1.6929	**43.00**	2 13/32	2.4063	61.119	3 7/16	3.4375	87.312
1 45/64	1.7031	43.259	2 7/16	2.4375	61.912		3.4646	**88.00**
	1.7126	43.500		2.4409	**62.00**	3 15/32	3.4687	88.106
1 23/32	1.7187	43.656	2 15/32	2.4687	62.706	**3 1/2**	3.5000	88.900
	1.7323	**44.00**		2.4803	**63.00**		3.5039	**89.00**
1 47/64	1.7344	44.053	**2 1/2**	2.5000	63.500	3 17/32	3.5313	89.694
1 3/4	1.7500	44.450		2.5197	**64.00**		3.5433	**90.00**
	1.7520	44.500	2 17/32	2.5313	64.294	3 9/16	3.5625	90.488
1 49/64	1.7656	44.847		2.5591	**65.00**		3.5827	**91.00**
	1.7717	**45.00**	2 9/16	2.5625	65.088	3 19/32	3.5937	91.281
1 25/32	1.7813	45.244	2 19/32	2.5937	65.881		3.6220	**92.00**
	1.7913	45.500		2.5984	**66.00**	3 5/8	3.6250	92.075
1 51/64	1.7969	45.641	2 5/8	2.6250	66.675	3 21/32	3.6492	92.689
	1.8110	**46.00**		2.6378	**67.00**		3.6614	**93.00**
1 13/16	1.8125	46.038	2 21/32	2.6563	67.469	3 11/16	3.6875	93.662
1 53/64	1.8281	46.434		2.6772	**68.00**		3.7008	**94.00**
	1.8307	46.500	2 11/16	2.6875	68.262	3 23/32	3.7187	94.456
1 27/32	1.8437	46.831		2.7165	**69.00**		3.7402	**95.00**
	1.8504	**47.00**	2 23/32	2.7187	69.056	**3 3/4**	3.7500	95.250
1 55/64	1.8594	47.228	**2 3/4**	2.7500	69.850		3.7795	**96.00**
	1.8701	47.500		2.7559	**70.00**	3 25/32	3.7813	96.044
1 7/8	1.8750	47.625	2 25/32	2.7813	70.644	3 13/16	3.8125	96.838
	1.8898	**48.00**		2.7953	**71.00**		3.8189	**97.00**
1 57/64	1.8906	48.022	2 13/16	2.8125	71.438	3 27/32	3.8437	97.631
1 29/32	1.9063	48.419		2.8346	**72.00**		3.8583	**98.00**
	1.9094	48.500	2 27/32	2.8437	72.231	3 7/8	3.8750	98.425
1 59/64	1.9219	48.816		2.8740	**73.00**		3.8976	**99.00**
	1.9291	**49.00**	2 7/8	2.8750	73.025	3 29/32	3.9063	99.219
1 15/16	1.9375	49.212	2 29/32	2.9063	73.819		3.9370	**100.00**
	1.9488	49.500		2.9134	**74.00**	3 15/16	3.9375	100.012
1 61/64	1.9531	49.609	2 15/16	2.9375	74.612	3 31/32	3.9687	100.806
	1.9685	**50.00**		2.9528	**75.00**	**4**	4.0000	101.604

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SPANNER SELECTION CHART

METRIC

Thread Size	Spanner Size A/F (mm)	Spanner Opening min (mm)	Spanner Opening max (mm)
M 1.6	3.2	3.22	3.28
M 2.0	4.0	4.02	4.12
M 2.5	5.0	5.02	5.12
M 3.0	5.5	5.52	5.62
M 4.0	7.0	7.03	7.15
M 5.0	8.0	8.03	8.15
M 6.0	10.0	10.04	10.19
M 7.0	11.0	11.04	11.19
M 8.0	13.0	13.04	13.24
M 10.0	17.0	17.05	17.30
M 12.0	19.0	19.06	19.36
M 14.0	22.0	22.06	22.36
M 16.0	24.0	24.06	24.36
M 18.0	27.0	27.08	27.48
M 20.0	30.0	30.08	30.48
M 22.0	32.0	32.08	32.48
M 24.0	36.0	36.10	36.60
M 27.0	41.0	41.10	41.60
M 30.0	46.0	46.10	46.60
M 33.0	50.0	50.10	50.60
M 36.0	55.0	55.12	55.72
M 39.0	60.0	60.12	60.72
M 42.0	65.0	65.12	65.72
M 45.0	70.0	70.12	70.72
M 48.0	75.0	75.15	75.85
M 52.0	80.0	80.15	80.85
M 56.0	85.0	85.15	85.85
M 60.0	90.0	90.15	90.85
M 64.0	95.0	95.15	95.85
M 68.0	100.0	100.15	100.85
M 72.0	105.0	105.20	106.00
M 76.0	110.0	110.20	111.00
M 80.0	115.0	115.20	116.00
M 85.0	120.0	120.20	121.00
M 90.0	130.0	130.20	131.00
M 95.0	135.0	135.20	136.00
M 100.0	145.0	145.20	146.00
M 105.0	150.0	150.25	151.25
M 110.0	155.0	155.25	156.25

UNF/UNC

Thread Size (inch)	Spanner Size A/F (inch)	Spanner Opening min (mm)	Spanner Opening max (mm)
1/4	7/16	11.18	11.33
5/16	1/2	12.80	12.95
3/8	9/16	14.38	14.55
7/16	5/8	15.98	16.15
1/2	3/4	19.18	19.38
9/16	13/16	20.78	20.98
5/8	15/16	23.98	24.21
3/4	1 1/8	28.75	29.01
7/8	1 5/16	33.53	33.81
1	1 1/2	38.30	38.61
1 1/8	1 11/16	43.08	43.38
1 1/4	1 7/8	47.88	48.21
1 3/8	2 1/16	52.68	53.04
1 1/2	2 1/4	57.45	57.84
1 3/4	2 5/8	67.03	67.46
2	3	76.61	77.09
2 1/4	3 3/8	86.18	86.72
2 1/2	3 3/4	95.76	96.34
2 3/4	4 1/8	105.33	105.97
3	4 1/2	114.91	115.57

BS (Whitworth)

Thread Size BS	Spanner Size A/F Whit	(inch)	(mm)	Nearest Fitting Spanner size A/F (inch)	(mm)
1/4	3/16 W	.445	11.30	7/16	12 mm
5/16	1/4 W	.525	13.33	17/32	14 mm
3/8	5/16 W	.600	15.24	19/32	16 mm
7/16	3/8 W	.710	18.03	23/32	18 mm
1/2	7/16 W	.820	20.83	13/16	21 mm
9/16	1/2 W	.920	23.37	15/16	24 mm
5/8	9/16 W	1.010	25.65	1	26 mm
3/4	11/16 W	1.200	30.48	1 1/4	31 mm
7/8	3/4 W	1.300	33.02	1 5/16	33 mm
1	7/8 W	1.480	37.59	1 1/4	38 mm
1 1/8	1 W	1.670	42.42	1 11/16	43 mm
1 1/4	1 1/8 W	1.860	47.24	1 7/8	48 mm
1 3/8	1 1/4 W	2.050	52.07	2 1/16	52 mm
1 1/2	1 3/8 W	2.220	56.39	2 1/4	57 mm
1 3/4	1 5/8 W	2.580	65.53	2 9/16	66 mm
2	1 3/4 W	2.760	70.10	2 3/4	70 mm

NOTE : Whitworth (W) = Old Standard
BS = New Standard

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TORQUE CONVERSION CHART

1 ft lb = 1.355817948 Nm 1 Nm = 0.737562149 ft lb

From foot-pound to Newton-metre

ft lb	Nm	ft lb	Nm
1	1.36	51	69.14
2	2.71	52	70.50
3	4.07	53	71.86
4	5.42	54	73.21
5	6.78	55	74.57
6	8.13	56	75.93
7	9.49	57	77.28
8	10.85	58	78.64
9	12.20	59	79.99
10	13.56	60	81.35
11	14.91	61	82.70
12	16.27	62	84.06
13	17.63	63	85.42
14	18.98	64	86.77
15	20.34	65	88.13
16	21.69	66	89.48
17	23.05	67	90.84
18	24.40	68	92.20
19	25.76	69	93.55
20	27.12	70	94.91
21	28.47	71	96.26
22	29.83	72	97.62
23	31.18	73	98.97
24	32.54	74	100.33
25	33.90	75	101.69
26	35.25	76	103.04
27	36.61	77	104.40
28	37.96	78	105.75
29	39.32	79	107.11
30	40.67	80	108.47
31	42.03	81	109.82
32	43.39	82	111.18
33	44.74	83	112.53
34	46.10	84	113.89
35	47.45	85	115.24
36	48.81	86	116.60
37	50.17	87	117.96
38	51.52	88	119.31
39	52.88	89	120.67
40	54.23	90	122.02
41	55.59	91	123.38
42	56.94	92	124.74
43	58.30	93	126.10
44	59.66	94	127.45
45	61.01	95	128.80
46	62.37	96	130.16
47	63.72	97	131.51
48	65.08	98	132.87
49	66.44	99	134.23
50	67.79	100	135.58

From Newton-metre to foot-pound

Nm	ft lb	Nm	ft lb
1	0.74	51	37.62
2	1.48	52	38.35
3	2.21	53	39.09
4	2.95	54	39.83
5	3.69	55	40.57
6	4.43	56	41.30
7	5.16	57	42.04
8	5.90	58	42.78
9	6.64	59	43.52
10	7.38	60	44.25
11	8.11	61	44.99
12	8.85	62	45.73
13	9.59	63	46.47
14	10.33	64	47.20
15	11.06	65	47.94
16	11.80	66	48.68
17	12.54	67	49.42
18	13.28	68	50.15
19	14.01	69	50.89
20	14.75	70	51.63
21	15.49	71	52.37
22	16.23	72	53.10
23	16.96	73	53.84
24	17.70	74	54.58
25	18.44	75	55.32
26	19.18	76	56.05
27	19.91	77	56.79
28	20.65	78	57.53
29	21.39	79	58.27
30	22.13	80	59.00
31	22.86	81	59.74
32	23.60	82	60.48
33	24.34	83	61.22
34	25.08	84	61.96
35	25.81	85	62.69
36	26.55	86	63.43
37	27.29	87	64.17
38	28.03	88	64.91
39	28.76	89	65.64
40	29.50	90	66.38
41	30.24	91	67.12
42	30.98	92	67.86
43	31.72	93	68.59
44	32.45	94	69.33
45	33.19	95	70.07
46	33.93	96	70.81
47	34.67	97	71.54
48	35.40	98	72.28
49	36.14	99	73.02
50	36.88	100	73.76

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SOCKET SIZING CROSS REFERENCE CHART

INCH TO METRIC

Socket Sizes (AF) (inch)	Metric Equivalent (mm)	Nearest Alternative Socket Size A/F (mm)	Diff. in mm.
3/16"	4.762	5mm	+0.238
7/32"	5.556	5.5mm	-0.056
1/4"	6.350		
9/32"	7.144		
5/16"	7.937	8mm	+0.063
11/32"	8.731	9mm	+0.269
3/8"	9.525	10mm	+0.475
7/16"	11.112	11mm	-0.112
15/32"	11.906	12mm	+0.094
1/2"	12.700	13mm	+0.300
17/32"	13.494	14mm	+0.506
9/16"	14.287		
19/32"	15.081	15mm	-0.081
5/8"	15.875	16mm	+0.125
11/16"	17.462		
3/4"	19.050	19mm	-0.050
25/32"	19.844	20mm	+0.156
13/16"	20.637	21mm	+0.363
7/8"	22.225	22mm	-0.225
15/16"	23.812	24mm	+0.188
1"	25.400	26mm	+0.600
1-1/16"	26.987	27mm	+0.013
1-1/8"	28.575	29mm	+0.425
1-3/16"	30.162	30mm	-0.162
1-1/4"	31.750	32mm	+0.250
1-5/16"	33.337	33mm	-0.337
1-3/8"	34.925	35mm	+0.075
1-7/16"	36.512	37mm	+0.488
1-1/2"	38.100	38mm	-0.100
1-9/16"	39.687	40mm	+0.313
1-5/8"	41.275	41mm	-0.275
1-11/16"	42.862	43mm	+0.138
1-3/4"	44.450	45mm	+0.550
1-13/16"	46.037	46mm	-0.037
1-7/8"	47.625	48mm	+0.375
1-15/16"	49.212	49mm	-0.212
2"	50.800	50mm	+0.200
2-1/16"	52.387	52mm	-0.387
2-1/8"	53.975	54mm	+0.025
2-3/16"	55.562	56mm	+0.438
2-1/4"	57.150	57mm	-0.150
2-5/16"	58.737	59mm	+0.263
2-3/8"	60.325	60mm	-0.325
2-7/16"	61.912	62mm	+0.088
2-1/2"	63.500	63mm	-0.500
2-9/16"	65.087	65mm	-0.087
2-5/8"	66.675	67mm	+0.325
2-11/16"	68.262		
2-3/4"	69.850	70mm	+0.150

Socket Sizes (inch)	Metric Equivalent (mm)	Nearest Alternative Socket Size A/F (mm)	Diff. in mm
2-13/16"	71.437		
2-7/8"	73.025		
2-15/16"	74.612	75mm	+0.388
3"	76.200		
3-1/16"	77.787		
3-1/8"	79.375	80mm	+0.625
3-3/16"	80.962		
3-1/4"	82.550		
3-5/16"	84.137		
3-3/8"	85.725		
3-7/16"	87.312		
3-1/2"	88.900		
3-9/16"	90.487	90mm	-0.487
3-5/8"	92.075		
3-3/4"	95.250	95mm	-0.250
3-13/16"	96.837		
3-7/8"	98.425		
3-15/16"	100.012	100mm	-0.012
4"	101.600		
4-1/16"	103.187		
4-1/8"	104.775	105mm	+0.225
4-3/16"	106.362		
4-1/4"	107.950		
4-5/16"	109.537	110mm	+0.463
4-3/8"	111.125		
4-7/16"	112.712		
4-1/2"	114.300	115mm	+0.700
4-5/8"	117.475		
4-3/4"	120.650	120mm	-0.650
4-7/8"	123.825		
5"	127.000		
5-1/8"	130.175	130mm	-0.175
5-1/4"	133.350		
5-3/8"	136.525		
5-7/16"	138.112		
5-1/2"	139.700	140mm	+0.300
5-5/8"	142.875		
5-3/4"	146.050		
5-7/8"	149.225		
6"	152.400	155mm	+2.600
6-1/8"	155.575	155mm	-0.575
6-1/4"	158.750	160mm	+1.250
6-3/8"	161.925		
6-1/2"	165.100	165mm	-0.100
6-5/8"	168.275		
6-3/4"	171.450		
6-7/8"	174.625		
7"	177.800		

13

SOCKET SIZING CROSS REFERENCE CHART

METRIC TO INCH

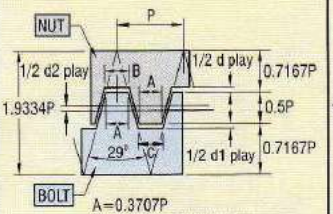
Socket Hex Size (AF) (mm)	Decimal Equivalent (inch)	Nearest Alternative Socket Size A/F (inch)	Diff. in mm
3.5mm	0.138"		
4mm	0.157"		
4.5mm	0.177"		
5mm	0.197"		
5.5mm	0.216"	7/32"	+0.056
6mm	0.236"		
7mm	0.275"		
8mm	0.315"	5/16"	-0.063
9mm	0.354"		
10mm	0.394"		
11mm	0.433"	7/16"	+0.112
12mm	0.472"	15/32"	-0.094
13mm	0.512"		
14mm	0.551"	9/16"	+0.287
15mm	0.590"	19/32"	+0.081
16mm	0.630"	5/8"	-0.127
17mm	0.669"		
18mm	0.709"		
19mm	0.748"	3/4"	+0.051
20mm	0.787"	25/32"	-0.157
21mm	0.827"		
22mm	0.866"	7/8"	+0.226
23mm	0.905"		
24mm	0.945"	15/16"	-0.188
25mm	0.984"	1"	+0.400
26mm	1.024"		
27mm	1.063"	1-1/16"	-0.012
28mm	1.102"		
29mm	1.142"		
30mm	1.181"	1-3/16"	+0.162
31mm	1.220"		
32mm	1.260"	1-1/4"	-0.250
33mm	1.299"	1-5/16"	+0.337
34mm	1.338"		
35mm	1.378"	1-3/8"	-0.075
36mm	1.417"	1-7/16"	+0.512
37mm	1.457"		
38mm	1.496"	1-1/2"	+0.100
39mm	1.535"		
40mm	1.575"	1-9/16"	-0.312
41mm	1.614"	1-5/8"	+0.275

Socket Hex Size (AF) (mm)	Decimal Equivalent (inch)	Nearest Alternative Socket Size A/F (inch)	Diff. in mm
42mm	1.653"		
43mm	1.693"	1-11/16"	-0.137
44mm	1.732"		
45mm	1.772"		
46mm	1.811"	1-13/16"	+0.037
47mm	1.850"		
48mm	1.890"		
49mm	1.929"		
50mm	1.968"		
52mm	2.047"	2-1/16"	+0.387
54mm	2.126"	2-1/8"	-0.025
55mm	2.165"	2-3/16"	+0.562
56mm	2.205"	2-3/16"	-0.437
57mm	2.244"	2-1/4"	+0.150
58mm	2.283"		
60mm	2.362"	2-3/8"	+0.325
62mm	2.441"	2-7/16"	-0.087
63mm	2.480"	2-1/2"	+0.500
65mm	2.559"	2-9/16"	+0.087
67mm	2.638"	2-5/8"	-0.325
70mm	2.756"	2-3/4"	-0.150
75mm	2.953"	2-15/16"	-0.387
80mm	3.150"		
85mm	3.346"	3-3/8"	+0.725
90mm	3.543"	3-9/16"	+0.487
95mm	3.740"	3-3/4"	+0.250
100mm	3.937"	3-15/16"	+0.012
105mm	4.134"	4-1/8"	-0.225
110mm	4.331"		
115mm	4.527"	4-1/2"	-0.700
120mm	4.724"	4-3/4"	+0.650
125mm	4.921"		
130mm	5.118"	5-1/8"	+0.175
135mm	5.315"		
140mm	5.512"	5-1/2"	-0.300
145mm	5.709"		
150mm	5.905"		
155mm	6.102"	6-1/8"	+0.575
160mm	6.299"		
165mm	6.496"	6-1/2"	+0.100
170mm	6.693"		

ABBREVIATIONS (SYMBOLS) USED FOR STANDARD THREADS

Symbol	Reference
ACME-G	Acme Thread – General Purpose
AMO	American Standard Microscope Objective Thread
ANPT	Aeronautical National Pipe Taper Thread
BA	British Association Standard Thread
BSB	British Standard Brass (26 tpi) Thread
BSCy	British Standard Cycle Thread
BS CON	British Standard Conduit Thread
BSF	British Standard Fine Thread
BS GAS	British Standard Gas Thread
BSPP	British Standard Pipe Parallel Thread
BSPT	British Standard Pipe Taper Thread
BSW	British Standard Whitworth (Coarse) Thread
M	ISO Metric (Coarse Pitch) Thread
ME	Model Engineers Thread
MF	ISO Metric (Fine Pitch) Thread
N	National 8, 12 and 16 Thread Series (8N, 12N, 16N)
N BUTT	National Buttress Thread
NC	National Coarse Thread Series
NEF	National Extra-Fine Thread Series
NF	National Fine Thread Series
NGO	National Gas Outlet Thread (specify right or left hand)
NGS	National Gas Straight Thread
NGT	National Gas Taper Thread (See also "SGT")
NH	National Hose (Garden & Fire Hose Coupling) Thread
NPT	National Pipe Taper Thread
NPTF	National Pipe Taper Fuel (Fuel & Oil) Thread
NPTR	National Pipe Taper Railing (Railing Joints) Thread
NPS	National Pipe Straight Thread
NPSC	National Pipe Straight Coupling (Pipe Couplings) Thread
NPSF	National Pipe Straight Fuel (Fuel & Oil) Thread
NPSH	National Pipe Straight Hose (Hose Couplings) Thread
NPSI	National Pipe Straight Intermediate Thread
NPSL	National Pipe Straight Lock (Lock Nut) Thread
NPSM	National Pipe Straight Mechanical Thread
NS	National Special Thread
PG	Panzerrohr-Gewinde (Steel Conduit Thread)
SB	Stove Bolt Standard Thread
SGT	Special Gas Taper Thread
STI	Special Thread Insert (for Helical Coil Wire Screw Thread Inserts)
STUB ACME	Stub Acme Thread
TR	Trapezoidal Thread
UN	Unified National (Constant-Pitch) Thread Series
UNC	Unified National Coarse Thread
UNEF	Unified National Extra-Fine Thread Series
UNF	Unified National Fine Thread
UNJ	Unified Nat. Thread Series with a 0.1501p to 0.1804p Controlled Root Radius (external threads)
UNM	Unified National Miniature Thread Series
UNR	Unified National Round (round root) Thread with a 0.1082p to 0.1443p Controlled Root Radius
UNS	Unified National Special Thread
V	A 60° "V" Thread with Truncated Crest and Root.
WHIT	Whitworth Form (Special) Thread

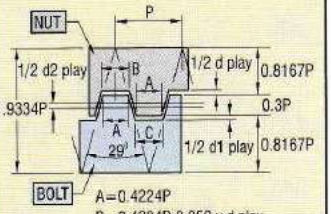
COMMON THREAD FORMS USED IN THE ENGINEERING INDUSTRY



A=0.3707P
B=0.3707P-0.259 x d play
C=0.3707P-0.259 (d1 play-d2 play)

ACME

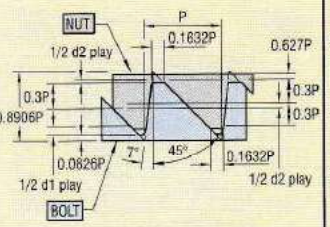
Use : Acme-General is used in the mechanical industry for motion transmission screws



A=0.4224P
B=0.4224P-0.259 x d play
C=0.4224P-0.259 (d1 play-d2 play)

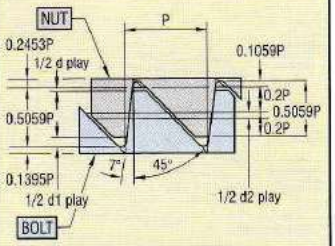
STUB ACME

Use : Stub Acme is used for motion transmission screws where normal Acme is too deep.



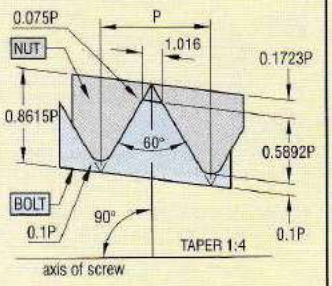
AMERICAN BUTTRESS

Use : Mechanical industry for motion transmission screws when the load is acting from one direction, e.g., in presses, rolling mills, etc.



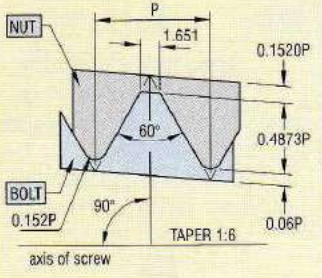
ENGLISH BUTTRESS

Use : Mechanical industry for motion transmission screws when the load is acting from one direction, e.g., in presses, rolling mills, etc.



API : TAPER 1:4 (V-0.040" FLAT)

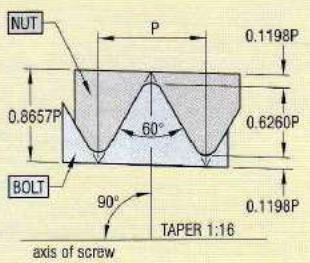
Use : Oil Industry



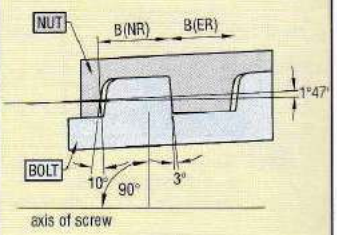
API : TAPER 1:6 (V-0.038"R)

Use : Oil Industry

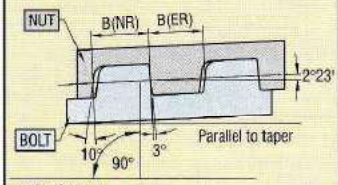
COMMON THREAD FORMS USED IN THE ENGINEERING INDUSTRY



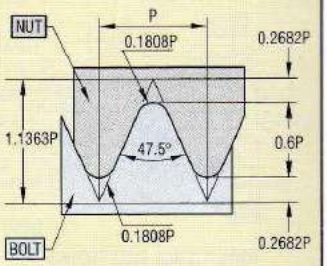
API : TAPER 1:16 (ROUNDED)
Use : Oil Industry



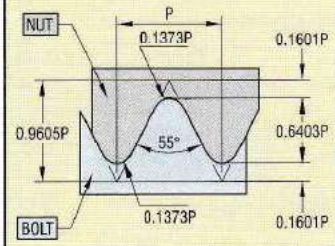
API BUTTRESS
Use : Oil industry for casing
Pipe size : 4 1/2" to 13-3/8"



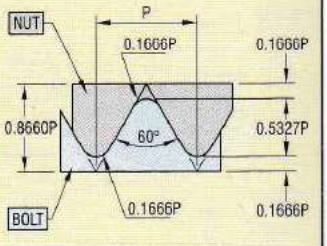
API BUTTRESS
Use : Oil industry for casing
Pipe size : 16" and larger



B.A.
(BRITISH ASSOCIATION)
Use : Fine - mechanical industry especially electrical utility, electronics.

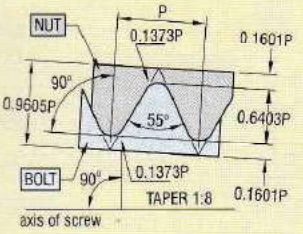


BSB
(BRITISH STANDARD BRASS - 26 TPI)
Use : Brass fittings and pipe couplings

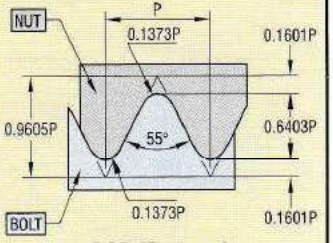


BSCy
(BRITISH STANDARD CYCLE)
Use : Bicycle industry

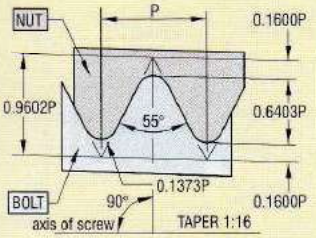
COMMON THREAD FORMS USED IN THE ENGINEERING INDUSTRY



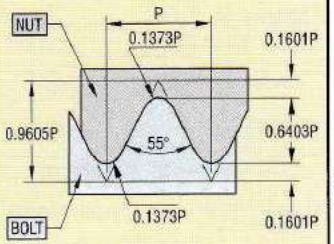
BS GAS
(BRITISH STANDARD GAS)
Use : Valves for gas cylinders and similar pressure vessels



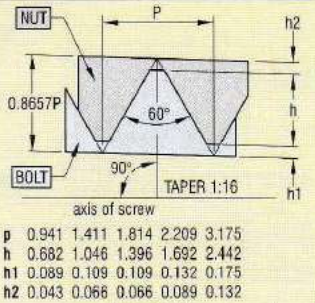
BSP (G SERIES)
(BRITISH STANDARD PIPE PARALLEL)
Use : Fittings and pipe couplings for gas, water and sewer lines



BSPT (Rc SERIES)
(BRITISH STD. PIPE TAPER)
Use : Pipe thread for steam, gas and water lines

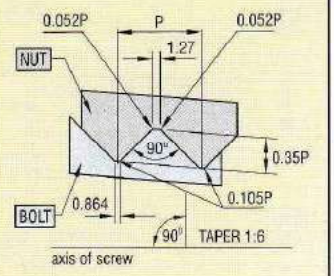


BSW / BSF
BSW (BRITISH STD. WHITWORTH)
BSF (BRITISH STD. FINE)
Use : As a general machine thread



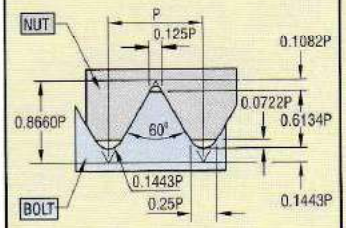
p	0.941	1.411	1.814	2.209	3.175
h	0.682	1.046	1.396	1.692	2.442
h1	0.089	0.109	0.109	0.132	0.175
h2	0.043	0.066	0.066	0.089	0.132

DRYSEAL
Use : Widely used for fluid-tight pipe couplings in the motor industry



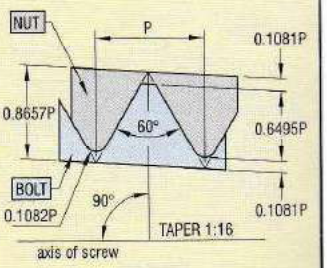
HUGHES H-90
Use : Oil industry

COMMON THREAD FORMS USED IN THE ENGINEERING INDUSTRY



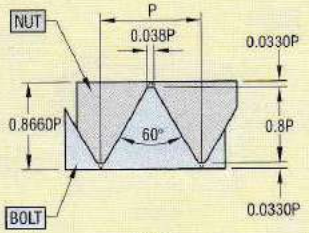
M
(ISO METRIC)

Use : All branches of mechanical industry



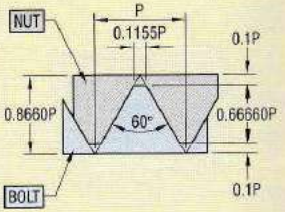
METRIC TAPER

Use : Grease fittings and pipe couplings



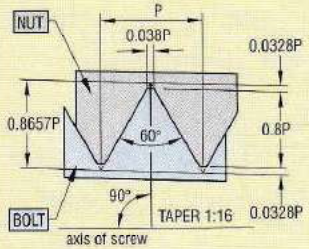
NPS
(NATIONAL PIPE STRAIGHT THREAD)

Use : Pipe couplings where there is no demand for fluid-tightness



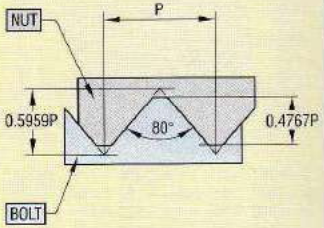
NPSL, NPSM, NPSH
(NATIONAL PIPE STRAIGHT THREAD)

Use : Mechanical couplings of tubings normally not fluid-tight



NPT
(NATIONAL PIPE TAPER)

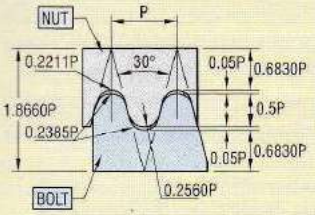
Use : Fittings and pipe couplings



PG
(PANZERROHR--GEWINDE)

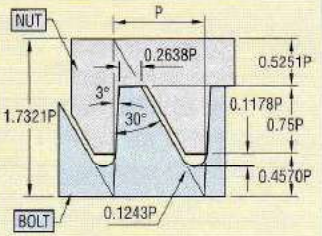
Use : Steel conduit (electric)

COMMON THREAD FORMS USED IN THE ENGINEERING INDUSTRY



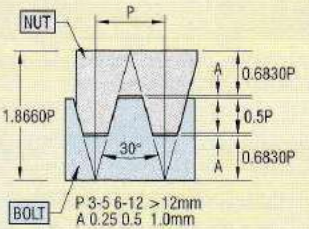
RD DIN 405
(ROUND DIN 405)

Use : Pipe couplings in fire protection and food industry



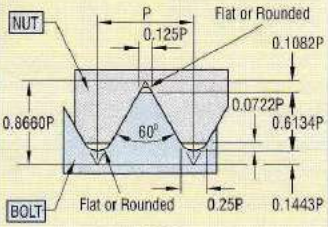
SAW-TOOTH THREAD 30° DIN 513

Use : Mechanical industry for motion transmission screws when the load is acting from one direction, e.g., presses, rolling mills, etc.



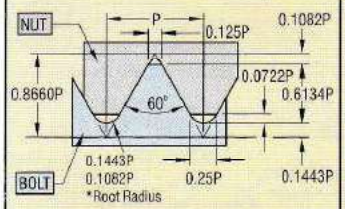
TR
(TRAPEZ) DIN 103

Use : Mechanical industry for motion transmission screws



UNC
(UNIFIED NATIONAL COARSE)
UNF
(UNIFIED NATIONAL FINE)

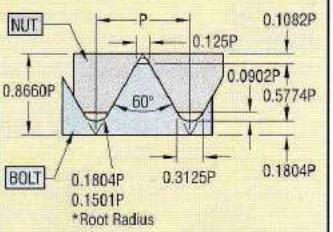
Use : Mechanical industry



UNR (UNIFIED NATIONAL ROUND)

* UNR - Unified National Round (round root) applies to External Threads. It is a UN thread in all respects except that the root radius must be rounded. Inspected only when specified.
Most manufacturers of externally thread fasteners produce UNR rolled threads rather than plain UN.

Use : Mechanical industry



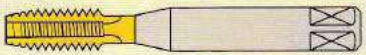
UNJ (CONTROLLED ROOT RADIUS)

* Applies to External Threads. Root Radius mandatory. Assemblies only with UNJ Internal threads. Mandatory inspection required.

Use : High Tensile Fasteners in Aircraft & Space industry

MAIN TYPES OF GROUND THREAD TAPS

Straight Flute Tap (Short Machine)

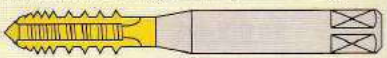


A general purpose tap for hand and machine operation suitable for short production runs. It performs best in materials where the cutting action results in chips which break up readily.

Right-Hand Spiral Flute Tap

This tap is designed primarily for machine tapping of blind holes. Most suitable for Aluminium and Soft Steel which produce long stringy chips. The cutting action of the spiral flute curls the chips and draws them out of the hole, allowing greater depth of threading.

Interrupted Thread Tap



The interrupted thread ensures less friction and hence, less resistance, which is particularly important when threading materials which are resilient & difficult to machine, e.g. Stainless Steel, Bronze. This design also facilitates ease of delivery of coolant to the cutting edge.

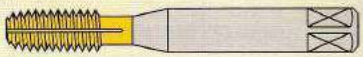
Spiral / Gun Point Straight Flute Tap

The spiral point tap is used mainly for tapping through holes. The point helps to cut the chips with a shearing action directing them ahead of the tap, leaving the flutes clear for the free flow of coolant to the point.

Fluteless Tap without Oil Grooves

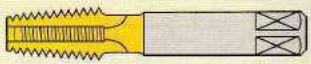
The fluteless tap is designed for machine tapping in Ductile materials. The fluteless design produces holes of increased strength with the absence of chips. A good lubricating fluid must be used with fluteless taps. Correct tapping drill sizes are equally important.

Fluteless Tap with Oil Grooves



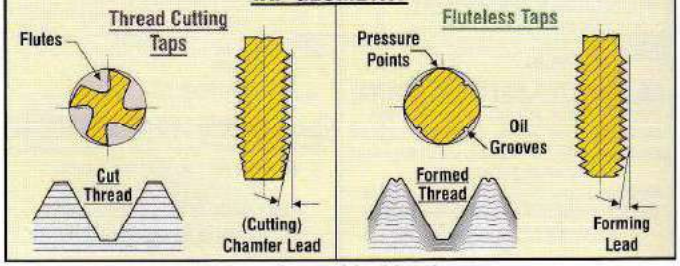
The application of the fluteless tap with oil grooves is the same as the fluteless tap, with the oil grooves helping to deliver lubricant easier to the tap point.

Taper Pipe Straight Flute Tap



Pipe taps are designed primarily for threading pipe fittings and are suitable for hand and machine use.

TAP GEOMETRY

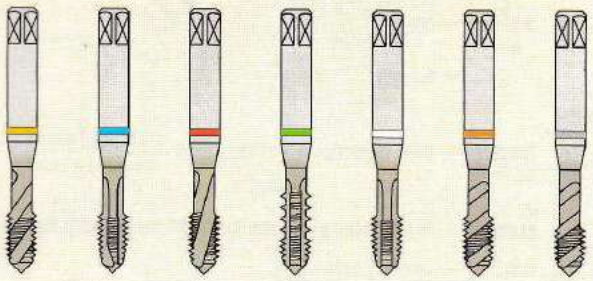


COLOUR CODED HIGH-PERFORMANCE TAPS & APPLICATIONS

High-Performance Machine Taps are produced from specially selected premium HSS-E Steel and are developed with unique geometries designed to provide accurately sized threads, superior tapping ability and longer tool life.

The taps come with colour coded rings and a variety of surface coatings, facilitating ease of selection and ensuring optimum performance in specific material groups.

Examples of High-Performance Taps with Colour Coded Rings



Most Tap Manufacturers adopt the following Colour Coding System.

Colour Rings	Applications	Material Examples	Tapping Speeds m/min. (Coated)
Yellow	Soft Long Chipping Materials ≤ 800 N/mm²	Free-cutting Steels, Structural Steels, Aluminium, Copper, Thermoplastics.	15 - 30 m/min.
Blue	Stainless Steels ≤ 1000 N/mm²	Free machining, Austenitic, Ferritic & Martensitic Stainless Steels.	5 - 15 m/min.
Red	Hard, Short, Chipping Materials ≤ 1200 N/mm²	Tool Steels, High-Speed Steels, Case Hardened Steels, Heat Treatable Steels.	2 - 15 m/min.
Green	Universal Applications Steels ≤ 1000 N/mm²	Free-Cutting Steels, Heat Treatable Steels, S. G. Iron, Nitriding & Case Hardened Steels.	15 - 30 m/min.
White	Cast Irons ≤ 850 N/mm²	Grey Cast Iron, Malleable Cast Iron, S. G. Iron, Brass & Bronze.	15 - 30 m/min.
Orange	Heat Resistant Alloys ≤ 1200 N/mm²	Nickel-based Alloys, Cobalt-based Alloys, Super Alloys with Hardness < 350 HB.	3 - 6 m/min.
Silver (MULTI)	Steels ≤ 1200 N/mm²	Structural Steels, Carbon Steels, Alloy Steels,	10 - 20 m/min.
	Stainless Steels ≤ 1000 N/mm²	Free Machining, Austenitic & Ferritic Stainless Steels	5 - 15 m/min.

NOTE : The above information is intended as a general guide only. For detailed and up to date application information, it is recommended to seek the advice of Tap Manufacturers.

CALCULATION OF TAPPING DRILL FORMULAE

FOR THREAD CUTTING TAPS

METRIC

$$\text{Drill Size} = \text{Basic Major Dia. of Thread} - \frac{\text{\% of Full Thread} \times \text{Pitch (mm)}}{76.98}$$

Example : To find Tapping Drill Size for M6 x 1.0 tap with 70% thread

$$\therefore \text{Drill Size} = 6.0 - \frac{70 \times 1.0}{76.98}$$

$$= 5.1 \text{ mm}$$

INCH

$$\text{Drill Size} = \text{Basic Major Dia. of Thread} - \left(.0130 \times \frac{\text{\% of Full Thread}}{\text{Threads per Inch}}\right)$$

Example : To find Tapping Drill Size for 1/4-20 tap with 75% thread

$$\therefore \text{Drill Size} = .2500 - \left(.0130 \times \frac{75}{20}\right)$$

$$= .2010 \text{ inches}$$

$$= 5.1 \text{ mm}$$

FOR FLUTELESS TAPS

METRIC

$$\text{Drill Size} = \text{Basic Major Dia. of Thread} - \frac{\text{\% of Full Thread} \times \text{Pitch (mm)}}{147.06}$$

Example : To find Tapping Drill Size for M6 x 1.0 tap with 70% thread

$$\therefore \text{Drill Size} = 6.0 - \frac{70 \times 1.0}{147.06}$$

$$= 5.5 \text{ mm}$$

INCH

$$\text{Drill Size} = \text{Basic Major Dia. of Thread} - \left(.0068 \times \frac{\text{\% of Full Thread}}{\text{Threads per Inch}}\right)$$

Example : To find Tapping Drill Size for 1/4-20 tap with 75% thread

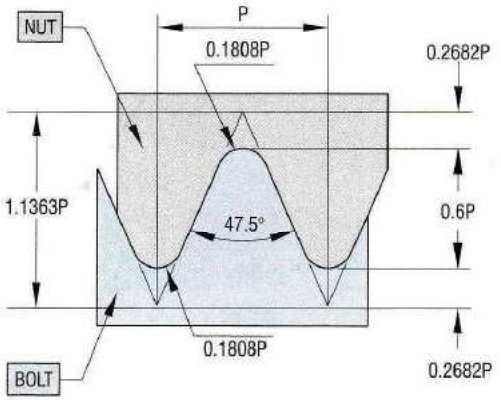
$$\therefore \text{Drill Size} = .2500 - \left(.0068 \times \frac{75}{20}\right)$$

$$= .2245 \text{ inches}$$

$$= 5.7 \text{ mm}$$

NOTE : It is advisable to use a good cutting oil or lubricant rather than coolant for Fluteless (Thread Forming) taps. Correct tapping drill sizes are equally important.

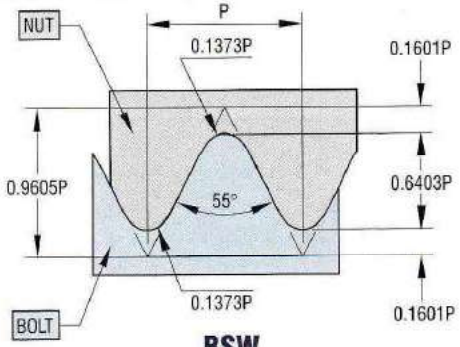
TAPPING DRILL SIZE FOR THREAD CUTTING TAPS



B.A. (BRITISH ASSOCIATION)

B.A. No.	Pitch (inch)	Basic Depth of Thread (inch)	Basic Major Diameter (inch)	Basic Effective Diameter (inch)	Basic Minor Diameter (inch)	Tapping Drill Size (mm)	Clearance Drill Size (mm)
0	.0394	0.0236	0.2362	0.2126	0.1890	**5.10**	6.10
1	.0354	0.0213	0.2087	0.1874	0.1661	**4.50**	5.40
2	.0319	0.0191	0.1850	0.1659	0.1468	**4.00**	4.80
3	.0287	0.0172	0.1614	0.1441	0.1268	**3.40**	4.20
4	.0260	0.0156	0.1417	0.1262	0.1106	**3.00**	3.70
5	.0232	0.0139	0.1260	0.1120	0.0980	**2.65**	3.30
6	.0209	0.0125	0.1102	0.0976	0.0850	**2.30**	2.90
7	.0189	0.0113	0.0984	0.0870	0.0756	**2.05**	2.60
8	.0169	0.0102	0.0866	0.0764	0.0661	**1.80**	2.25
9	.0154	0.0092	0.0748	0.0656	0.0563	**1.55**	1.95
10	.0138	0.0083	0.0669	0.0587	0.0504	**1.40**	1.75
11	.0122	0.0073	0.0591	0.0518	0.0445	**1.20**	1.60
12	.0110	0.0066	0.0512	0.0445	0.0378	**1.05**	1.40
13	.0098	0.0059	0.0472	0.0413	0.0354	**0.98**	1.30
14	.0091	0.0054	0.0394	0.0339	0.0283	**0.80**	1.10
15	.0083	0.0050	0.0354	0.0305	0.0256	**0.70**	0.98
16	.0075	0.0045	0.0311	0.0266	0.0220	**0.60**	0.88

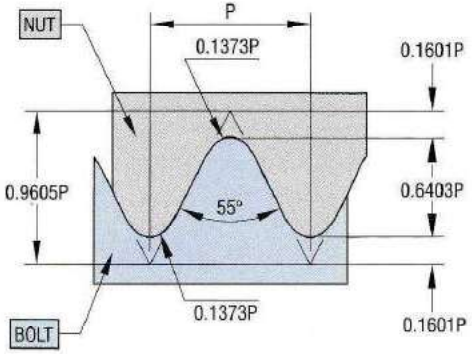
TAPPING DRILL SIZE FOR THREAD CUTTING TAPS



BSW
(BRITISH STANDARD WHITWORTH)

Nom. Dia. BSW (inch)	Threads per Inch (t.p.i.)	Basic Depth of Thread (inch)	Basic Major Diameter (inch)	Basic Effective Diameter (inch)	Basic Minor Diameter (inch)	Tapping Drill Size (mm)	Clearance Drill Size (mm)
1/16	60	.0107	0.0625	0.0518	0.0411	1.20	1.65
3/32	48	.0133	0.0938	0.0805	0.0672	1.85	2.50
1/8	40	.0160	0.1250	0.1090	0.0930	2.55	3.30
5/32	32	.0200	0.1562	0.1362	0.1162	3.20	4.10
3/16	24	.0267	0.1875	0.1608	0.1341	3.70	4.90
7/32	24	.0267	0.2188	0.1921	0.1654	4.50	5.70
1/4	20	.0320	0.2500	0.2180	0.1860	5.10	6.50
5/16	18	.0356	0.3125	0.2769	0.2413	6.50	8.10
3/8	16	.0400	0.3750	0.3350	0.2950	7.90	9.70
7/16	14	.0457	0.4375	0.3918	0.3461	9.30	11.30
1/2	12	.0534	0.5000	0.4466	0.3932	10.50	13.00
9/16	12	.0534	0.5625	0.5091	0.4557	12.10	14.50
5/8	11	.0582	0.6250	0.5668	0.5086	13.50	16.25
11/16	11	.0582	0.6875	0.6293	0.5711	15.00	17.75
3/4	10	.0640	0.7500	0.6860	0.6220	16.25	19.25
13/16	10	.0640	0.8125	0.7485	0.6845	18.00	21.00
7/8	9	.0711	0.8750	0.8039	0.7328	19.25	22.50
15/16	9	.0711	0.9375	0.8664	0.7953	20.75	24.00
1	8	.0800	1.0000	0.9200	0.8400	22.00	25.75
1 1/8	7	.0915	1.1250	1.0335	0.9420	24.75	29.00
1 1/4	7	.0915	1.2500	1.1585	1.0670	28.00	32.00
1 3/8	6	.1067	1.3750	1.2683	1.1616	30.25	35.50
1 1/2	6	.1067	1.5000	1.3933	1.2866	33.50	38.50
1 5/8	5	.1281	1.6250	1.4969	1.3688	35.50	41.50
1 3/4	5	.1281	1.7500	1.6219	1.4938	39.00	45.00
1 7/8	4 1/2	.1423	1.8750	1.7327	1.5904	41.50	48.00
2	4 1/2	.1423	2.0000	1.8577	1.7154	44.50	51.00
2 1/4	4	.1601	2.2500	2.0899	1.9298	51.00	58.00
2 1/2	4	.1601	2.5000	2.3399	2.1798	57.00	64.00

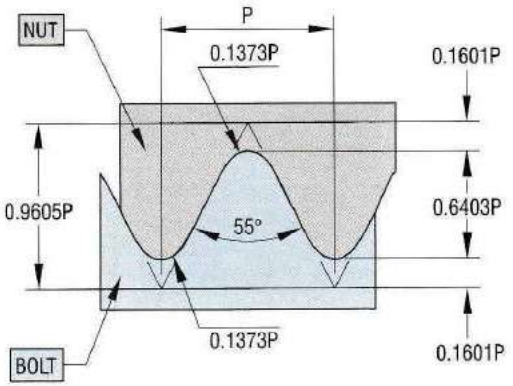
TAPPING DRILL SIZE FOR THREAD CUTTING TAPS



BSF
(BRITISH STANDARD FINE)

Nom. Dia. BSF (inch)	Threads per Inch (t.p.i.)	Basic Depth Thread (inch)	Basic Major Diameter (inch)	Basic Effect Diameter (inch)	Basic Minor Diameter (inch)	Tapping Drill Size (mm)	Clearance Drill Size (mm)
3/16	32	.0200	0.1875	0.1675	0.1475	4.00	4.90
7/32	28	.0229	0.2188	0.1959	0.1730	4.60	5.70
1/4	26	.0246	0.2500	0.2254	0.2008	5.30	6.50
5/16	22	.0291	0.3125	0.2834	0.2543	6.80	8.10
3/8	20	.0320	0.3750	0.3430	0.3110	8.30	9.70
7/16	18	.0356	0.4375	0.4019	0.3663	9.70	11.30
1/2	16	.0400	0.5000	0.4600	0.4200	11.10	13.00
9/16	16	.0400	0.5625	0.5225	0.4825	12.70	14.50
5/8	14	.0457	0.6250	0.5793	0.5336	14.00	16.25
11/16	14	.0457	0.6875	0.6418	0.5961	15.50	17.75
3/4	12	.0534	0.7500	0.6966	0.6432	16.75	19.25
7/8	11	.0582	0.8750	0.8168	0.7586	19.75	22.50
1	10	.0640	1.0000	0.9360	0.8720	22.75	25.75
1 1/8	9	.0711	1.1250	1.0539	0.9828	25.50	29.00
1 1/4	9	.0711	1.2500	1.1789	1.1078	28.50	32.00
1 3/8	8	.0800	1.3750	1.2950	1.2150	31.50	35.50
1 1/2	8	.0800	1.5000	1.4200	1.3400	34.50	38.50
1 3/4	7	.0915	1.7500	1.6585	1.5670	41.00	45.00
2	7	.0915	2.0000	1.9085	1.8170	47.00	52.00
2 1/4	6	.1067	2.2500	2.1433	2.0366	53.00	58.00
2 1/2	6	.1067	2.5000	2.3933	2.2866	58.00	64.00

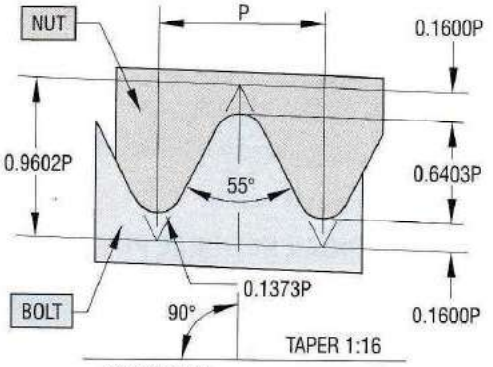
TAPPING DRILL SIZE FOR THREAD CUTTING TAPS

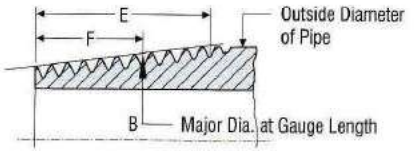


BSP (BRITISH STANDARD PIPE)

Nom. Dia. BSP (inch)	Threads per Inch (t.p.i.)	Basic Major Diameter (inch)	Basic Depth Thread (inch)	Basic Effective Diameter (inch)	Basic Minor Diameter (inch)	Tapping Drill (Bore) Size Rp Series (Parallel) (BSPP) (mm)	G Series (Fastening) (BSPF) (mm)
1/16	28	0.304	.02290	0.2812	0.2583	6.60	6.80
1/8	28	0.383	.0229	0.3601	0.3372	8.60	8.80
1/4	19	0.518	.0337	0.4843	0.4506	11.50	11.80
3/8	19	0.656	.0337	0.6223	0.5886	15.00	15.25
1/2	14	0.825	.0457	0.7793	0.7336	18.50	19.00
5/8	14	0.902	.0457	0.8563	0.8106	20.50	21.00
3/4	14	1.041	.0457	0.9953	0.9496	24.00	24.50
7/8	14	1.189	.0457	1.1433	1.0976	27.75	28.25
1	11	1.309	.0582	1.2508	1.1926	30.25	30.75
1 1/4	11	1.650	.0582	1.5918	1.5336	39.00	39.50
1 1/2	11	1.882	.0582	1.8238	1.7656	45.00	45.50
1 3/4	11	2.116	.0582	2.0578	1.9996	50.50	51.00
2	11	2.347	.0582	2.2888	2.2306	56.50	57.00
2 1/4	11	2.587	.0582	2.5288	2.4706	62.70	62.70
2 1/2	11	2.960	.0582	2.9018	2.8436	72.10	72.10
2 3/4	11	3.210	.0582	3.1518	3.0936	78.50	78.50
3	11	3.460	.0582	3.4018	3.3436	84.80	84.80
3 1/2	11	3.950	.0582	3.8918	3.8336	97.30	97.30
4	11	4.450	.0582	4.3918	4.3336	110.00	110.00
5	11	5.450	.0582	5.3918	5.3336	135.40	135.40
6	11	6.450	.0582	6.3918	6.3336	160.80	160.80

TAPPING DRILL SIZE FOR THREAD CUTTING TAPS

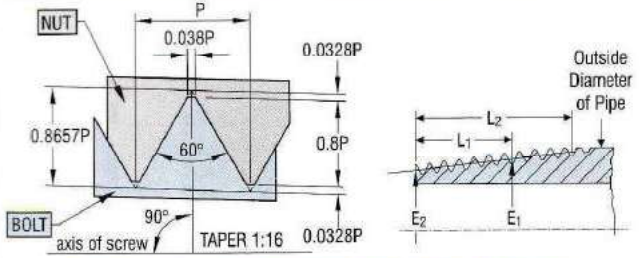




BSPT (Rc SERIES) (BRITISH STANDARD PIPE TAPER)

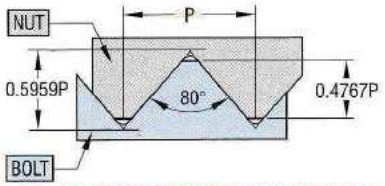
Nom. Size BSPT (inch)	Threads per Inch (t.p.i.)	Basic Depth of Thread (Inch)	Diameter at Gauge Plane Major Diameter (B) (inch)	Effective Diameter (inch)	Minor Diameter (inch)	Gauge Length (F) (inch)	Length of Useful Thread (E) (inch)	Tapping Drill Size (without reamer) (mm)
1/16	28	0.0229	0.304	0.2812	0.2583	0.1563	0.2545	6.40
1/8	28	0.0229	0.383	0.3601	0.3372	0.1563	0.2545	8.40
1/4	19	0.0337	0.518	0.4843	0.4506	0.2367	0.3814	11.20
3/8	19	0.0337	0.656	0.6223	0.5886	0.2500	0.3947	14.75
1/2	14	0.0457	0.825	0.7793	0.7336	0.3214	0.5178	18.25
3/4	14	0.0457	1.041	0.9953	0.9496	0.3750	0.5714	23.75
1	11	0.0582	1.309	1.2508	1.1926	0.4091	0.6591	30.00
1 1/4	11	0.0582	1.650	1.5918	1.5336	0.5000	0.7500	38.50
1 1/2	11	0.0582	1.882	1.8238	1.7656	0.5000	0.7500	44.50
2	11	0.0582	2.347	2.2888	2.2306	0.6250	0.9204	56.00
2 1/2	11	0.0582	2.960	2.9018	2.8436	0.6875	1.0511	71.00

TAPPING DRILL SIZE FOR THREAD CUTTING TAPS



NPT (AMERICAN NATIONAL PIPE TAPER)

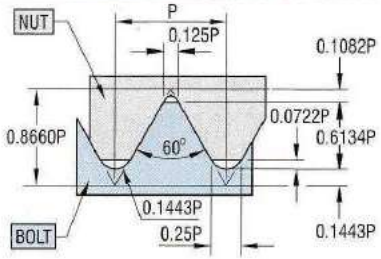
Nom. Size NPT (inch)	Threads per Inch (t.p.i.)	Basic Depth of Thread (inch)	Outside Diameter of Pipe (inch)	Eff. Dia. at Small End of Ext. Thd. (E_2) (inch)	Eff. Dia. at Large End of Ext. Thd. (E_1) (inch)	Gauge Length L_1 (inch)	Length of Useful Thread L_2 (inch)	Tapping Drill Size (without reamer) (mm)
1/16	27	0.0296	0.3125	0.2712	0.2812	0.1598	0.2611	**6.30**
1/8	27	0.0296	0.4050	0.3635	0.3736	0.1613	0.2639	**8.70**
1/4	18	0.0444	0.5400	0.4774	0.4916	0.2275	0.4018	**11.10**
3/8	18	0.0444	0.6750	0.6120	0.6270	0.2398	0.4078	**14.50**
1/2	14	0.0571	0.8400	0.7584	0.7784	0.3199	0.5337	**18.00**
3/4	14	0.0571	1.0500	0.9677	0.9889	0.3391	0.5457	**23.25**
1	11 1/2	0.0696	1.3150	1.2136	1.2386	0.3997	0.6828	**29.00**
1 1/4	11 1/2	0.0696	1.6600	1.5571	1.5834	0.4197	0.7068	**38.00**
1 1/2	11 1/2	0.0696	1.9000	1.7961	1.8223	0.4197	0.7235	**44.00**
2	11 1/2	0.0696	2.3750	2.2690	2.2963	0.4354	0.7565	**56.00**
2 1/2	8	0.1000	2.8750	2.7195	2.7622	0.6825	1.1375	**67.00**



PG (PANZERROHR-GEWINDE)

Designation Pg	Threads per Inch (t.p.i.)	Basic Major Diameter (mm)	Basic Pitch Diameter (mm)	Basic Minor Diameter (mm)	Tapping Drill Size (mm)	Clearance Drill Size (mm)
Pg 7	20	12.5	11.89	11.28	**11.30**	12.60
Pg 9	18	15.2	14.53	13.86	**13.90**	15.30
Pg 11	18	18.6	17.93	17.26	**17.30**	18.70
Pg 13.5	18	20.4	19.73	19.06	**19.10**	20.50
Pg 16	18	22.5	21.83	21.16	**21.20**	22.75
Pg 21	16	28.3	27.54	26.78	**26.80**	28.75
Pg 29	16	37.0	36.24	35.48	**35.50**	37.25
Pg 36	16	47.0	46.24	45.48	**45.50**	47.25
Pg 42	16	54.0	53.24	52.48	**52.50**	54.25
Pg 48	16	59.3	58.54	57.78	**57.80**	59.55

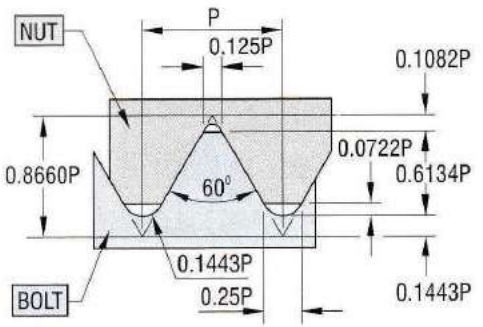
TAPPING DRILL SIZE FOR THREAD CUTTING TAPS



M (ISO) METRIC COARSE

Nominal Diameter x Pitch M (mm)	Basic Major Diameter (mm)	Basic Effective Diameter (mm)	Basic Minor Dia. of Ext. Thd (mm)	Basic Minor Dia. of Int. Thd (mm)	Tapping Drill Size (mm)	Clearance Drill Size (mm)
M 1.0 x 0.25	1.00	0.838	0.693	0.729	**0.75**	1.05
M 1.1 x 0.25	1.10	0.938	0.793	0.829	**0.85**	1.15
M 1.2 x 0.25	1.20	1.038	0.893	0.929	**0.95**	1.25
M 1.4 x 0.30	1.40	1.205	1.032	1.075	**1.10**	1.45
M 1.6 x 0.35	1.60	1.373	1.170	1.221	**1.25**	1.65
M 1.8 x 0.35	1.80	1.573	1.370	1.421	**1.45**	1.85
M 2.0 x 0.40	2.00	1.740	1.509	1.567	**1.60**	2.05
M 2.2 x 0.45	2.20	1.908	1.648	1.713	**1.75**	2.25
M 2.5 x 0.45	2.50	2.208	1.948	2.013	**2.05**	2.60
M 3.0 x 0.50	3.00	2.675	2.387	2.459	**2.50**	3.10
M 3.5 x 0.60	3.50	3.110	2.764	2.850	**2.90**	3.60
M 4.0 x 0.70	4.00	3.545	3.141	3.242	**3.30**	4.10
M 4.5 x 0.75	4.50	4.013	3.580	3.688	**3.70**	4.60
M 5.0 x 0.80	5.00	4.480	4.019	4.134	**4.20**	5.10
M 6.0 x 1.00	6.00	5.350	4.773	4.917	**5.00**	6.10
M 7.0 x 1.00	7.00	6.350	5.773	5.917	**6.00**	7.20
M 8.0 x 1.25	8.00	7.188	6.466	6.647	**6.80**	8.20
M 9.0 x 1.25	9.00	8.188	7.466	7.647	**7.80**	9.20
M 10.0 x 1.50	10.00	9.026	8.160	8.376	**8.50**	10.20
M 11.0 x 1.50	11.00	10.026	9.160	9.376	**9.50**	11.20
M 12.0 x 1.75	12.00	10.863	9.853	10.106	**10.20**	12.20
M 14.0 x 2.00	14.00	12.701	11.546	11.835	**12.00**	14.25
M 16.0 x 2.00	16.00	14.701	13.546	13.835	**14.00**	16.25
M 18.0 x 2.50	18.00	16.376	14.933	15.294	**15.50**	18.25
M 20.0 x 2.50	20.00	18.376	16.933	17.294	**17.50**	20.25
M 22.0 x 2.50	22.00	20.376	18.933	19.294	**19.50**	22.25
M 24.0 x 3.00	24.00	22.051	20.319	20.752	**21.00**	24.25
M 27.0 x 3.00	27.00	25.051	23.319	23.752	**24.00**	27.25
M 30.0 x 3.50	30.00	27.727	25.706	26.211	**26.50**	30.50
M 33.0 x 3.50	33.00	30.727	28.706	29.211	**29.50**	33.50
M 36.0 x 4.00	36.00	33.402	31.093	31.670	**32.00**	36.50
M 39.0 x 4.00	39.00	36.402	34.093	34.670	**35.00**	39.50
M 42.0 x 4.50	42.00	39.077	36.479	37.129	**37.50**	42.50
M 45.0 x 4.50	45.00	42.077	39.479	40.129	**40.50**	45.50
M 48.0 x 5.00	48.00	44.752	41.866	42.587	**43.00**	48.50
M 52.0 x 5.00	52.00	48.752	45.866	46.587	**47.00**	53.00
M 56.0 x 5.50	56.00	52.428	49.252	50.046	**50.50**	57.00

TAPPING DRILL SIZE FOR THREAD CUTTING TAPS



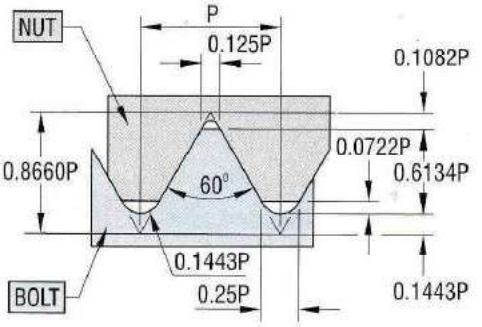
(ISO) METRIC FINE

Nominal Diameter x Pitch M (mm)	Basic Major Diameter (mm)	Basic Effective Diameter (mm)	Basic Minor Dia. of Ext. Thd. (mm)	Basic Minor Dia. of Int. Thd. (mm)	Tapping Drill Size (mm)	Clearance Drill Size (mm)
M 3.0 x 0.35	3.00	2.773	2.570	2.621	**2.65**	3.10
M 4.0 x 0.50	4.00	3.675	3.387	3.459	**3.50**	4.10
M 5.0 x 0.50	5.00	4.675	4.387	4.459	**4.50**	5.10
M 6.0 x 0.75	6.00	5.513	5.080	5.188	**5.20**	6.10
M 7.0 x 0.75	7.00	6.513	6.080	6.188	**6.20**	7.20
M 8.0 x 1.00	8.00	7.350	6.773	6.917	**7.00**	8.20
M 10.0 x 1.25	10.00	9.188	8.466	8.647	**8.80**	10.20
M 12.0 x 1.25	12.00	11.188	10.466	10.647	**10.80**	12.20
M 14.0 x 1.50	14.00	13.026	12.160	12.376	**12.50**	14.25
M 16.0 x 1.50	16.00	15.026	14.160	14.376	**14.50**	16.25
M 18.0 x 1.50	18.00	17.026	16.160	16.376	**16.50**	18.25
M 20.0 x 1.50	20.00	19.026	18.160	18.376	**18.50**	20.25
M 22.0 x 1.50	22.00	21.026	20.160	20.376	**20.50**	22.25
M 24.0 x 2.00	24.00	22.701	21.546	21.835	**22.00**	24.25
M 27.0 x 2.00	27.00	25.701	24.506	24.835	**25.00**	27.25
M 30.0 x 2.00	30.00	28.701	27.546	27.835	**28.00**	30.50

(ISO) METRIC CONDUIT

M 16.0 x 1.50	16.00	15.026	14.160	14.376	**14.50**	16.25
M 20.0 x 1.50	20.00	19.026	18.160	18.376	**18.50**	20.25
M 25.0 x 1.50	25.00	24.026	23.160	23.376	**23.50**	25.25
M 32.0 x 1.50	32.00	31.026	30.160	30.376	**30.50**	32.50
M 40.0 x 1.50	40.00	39.026	38.160	38.376	**38.50**	40.50
M 50.0 x 1.50	50.00	49.026	48.160	48.376	**48.50**	50.50

TAPPING DRILL SIZE FOR THREAD CUTTING TAPS



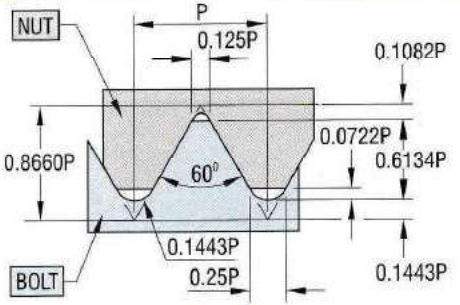
(ISO) METRIC SPECIAL PITCHES

Nominal Diameter x Pitch M (mm)	Basic Major Diameter (mm)	Basic Effective Diameter (mm)	Basic Minor Dia. of Ext. Thd. (mm)	Basic Minor Dia. of Int. Thd. (mm)	Tapping Drill Size (mm)	Clearance Drill Size (mm)
M 1.7 x 0.35	1.70	1.473	1.270	1.321	**1.35**	1.80
M 2.0 x 0.45	2.00	1.708	1.448	1.513	**1.55**	2.10
M 2.3 x 0.40	2.30	2.040	1.809	1.867	**1.90**	2.40
M 2.6 x 0.45	2.60	2.308	2.048	2.113	**2.15**	2.70
M 3.0 x 0.60	3.00	2.610	2.264	2.350	**2.40**	3.10
M 4.0 x 0.75	4.00	3.513	3.308	3.188	**3.20**	4.10
M 5.0 x 0.90	5.00	4.415	3.896	4.026	**4.10**	5.10
M 5.5 x 0.90	5.50	4.915	4.396	4.526	**4.60**	5.60
M 8.0 x 0.75	8.00	7.513	7.080	7.188	**7.20**	8.20
M 9.0 x 1.00	9.00	8.350	7.773	7.917	**8.00**	9.20
M 10.0 x 0.75	10.00	9.513	9.080	9.188	**9.20**	10.20
M 10.0 x 1.00	10.00	9.350	8.773	8.917	**9.00**	10.20
M 12.0 x 1.00	12.00	11.350	10.773	10.917	**11.00**	12.20
M 12.0 x 1.50	12.00	11.026	10.160	10.376	**10.50**	12.20
M 14.0 x 1.25	14.00	13.188	12.466	12.647	**12.80**	14.25
M 16.0 x 1.00	16.00	15.350	14.773	14.917	**15.00**	16.25
M 20.0 x 1.00	20.00	19.350	18.773	18.917	**19.00**	20.25
M 20.0 x 2.00	20.00	18.701	17.546	17.835	**18.00**	20.25
M 24.0 x 1.00	24.00	23.350	22.773	22.917	**23.00**	24.25
M 24.0 x 1.50	24.00	23.026	22.160	22.376	**22.50**	24.25
M 25.0 x 1.50	25.00	24.026	23.160	23.376	**23.50**	25.25
M 32.0 x 1.50	32.00	31.026	30.160	30.376	**30.50**	32.50

(ISO) METRIC SPARKPLUG

M 10.0 x 1.00	10.00	9.350	8.773	8.917	**9.00**	10.20
M 12.0 x 1.25	12.00	11.188	10.466	10.647	**10.80**	12.20
M 14.0 x 1.25	14.00	13.188	12.466	12.647	**12.80**	14.25
M 18.0 x 1.50	18.00	17.026	16.160	16.376	**16.50**	18.25

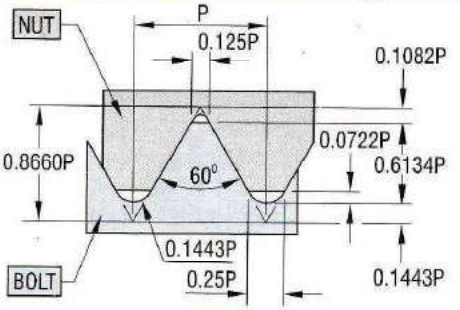
TAPPING DRILL SIZE FOR THREAD CUTTING TAPS



UNC
(UNIFIED NATIONAL COARSE)

Nom. Dia. UNC (No./inch)	Threads per inch (t.p.i.)	Basic Major Diameter (inch)	Basic Effective Diameter (inch)	Basic Minor Dia. of Ext. Thd. (inch)	Basic Minor Dia. of Int. Thd. (inch)	Tapping Drill Size (mm)	Clearance Drill Size (mm)
No. 1	64	0.0730	0.0629	0.0538	0.0561	1.55	1.95
No. 2	56	0.0860	0.0744	0.0641	0.0667	1.85	2.30
No. 3	48	0.0990	0.0855	0.0734	0.0764	2.10	2.65
No. 4	40	0.1120	0.0958	0.0813	0.0849	2.35	2.95
No. 5	40	0.1250	0.1088	0.0943	0.0979	2.65	3.30
No. 6	32	0.1380	0.1177	0.0997	0.1042	2.85	3.60
No. 8	32	0.1640	0.1437	0.1257	0.1302	3.50	4.30
No.10	24	0.1900	0.1629	0.1389	0.1449	3.90	4.90
No.12	24	0.2160	0.1889	0.1649	0.1709	4.50	5.60
1/4	20	0.2500	0.2175	0.1887	0.1959	5.10	6.50
5/16	18	0.3125	0.2764	0.2443	0.2524	6.60	8.10
3/8	16	0.3750	0.3344	0.2983	0.3073	8.00	9.70
7/16	14	0.4375	0.3911	0.3499	0.3602	9.40	11.30
1/2	13	0.5000	0.4500	0.4056	0.4167	10.80	13.00
9/16	12	0.5625	0.5084	0.4603	0.4723	12.20	14.50
5/8	11	0.6250	0.5660	0.5135	0.5266	13.50	16.25
3/4	10	0.7500	0.6850	0.6273	0.6417	16.50	19.25
7/8	9	0.8750	0.8028	0.7387	0.7547	19.50	22.50
1	8	1.0000	0.9188	0.8466	0.8647	22.25	25.75
1 1/8	7	1.1250	1.0322	0.9497	0.9704	25.00	29.00
1 1/4	7	1.2500	1.1572	1.0747	1.0954	28.00	32.00
1 3/8	6	1.3750	1.2667	1.1705	1.1946	30.75	35.50
1 1/2	6	1.5000	1.3917	1.2955	1.3196	34.00	38.50
1 3/4	5	1.7500	1.6201	1.5046	1.5335	39.50	45.00
2	4 1/2	2.0000	1.8557	1.7274	1.7594	45.00	51.00
2 1/4	4 1/2	2.2500	2.1057	1.9774	2.0094	52.00	58.00

TAPPING DRILL SIZE FOR THREAD CUTTING TAPS



UNF
(UNIFIED NATIONAL FINE)

Nom. Dia. UNF (No./inch)	Threads per inch (t.p.i.)	Basic Major Diameter (inch)	Basic Effective Diameter (inch)	Basic Minor Dia. of Ext. Thd. (inch)	Basic Minor Dia. of Int. Thd. (inch	Tapping Drill Size (mm)	Clearance Drill Size (mm)
No. 0	80	0.0600	0.0519	0.0447	0.0465	1.25	1.60
No. 1	72	0.0730	0.0640	0.0560	0.0580	1.55	1.95
No. 2	64	0.0860	0.0759	0.0668	0.0691	1.90	2.30
No. 3	56	0.0990	0.0874	0.0771	0.0797	2.15	2.65
No. 4	48	0.1120	0.0985	0.0864	0.0894	2.40	2.95
No. 5	44	0.1250	1.1102	0.0971	0.1004	2.70	3.30
No. 6	40	0.1380	0.1218	0.1073	0.1109	2.95	3.60
No. 8	36	0.1640	0.1460	0.1299	0.1339	3.50	4.30
No.10	32	0.1900	0.1697	0.1517	0.1562	4.10	4.90
No.12	28	0.2160	0.1928	0.1722	0.1773	4.70	5.60
1/4	28	0.2500	0.2268	0.2062	0.2113	5.50	6.50
5/16	24	0.3125	0.2854	0.2614	0.2674	6.90	8.10
3/8	24	0.3750	0.3479	0.3239	0.3299	8.50	9.70
7/16	20	0.4375	0.4050	0.3762	0.3834	9.90	11.30
1/2	20	0.5000	0.4675	0.4387	0.4459	11.50	13.00
9/16	18	0.5625	0.5264	0.4943	0.5024	12.90	14.50
5/8	18	0.6250	0.5889	0.5568	0.5649	14.50	16.25
3/4	16	0.7500	0.7094	0.6733	0.6823	17.50	19.25
7/8	14	0.8750	0.8286	0.7874	0.7977	20.40	22.50
1	12	1.0000	0.9459	0.8978	0.9098	23.25	25.75
1 1/8	12	1.1250	1.0709	1.0228	1.0348	26.50	29.00
1 1/4	12	1.2500	1.1959	1.1478	1.1598	29.50	32.00
1 3/8	12	1.3750	1.3209	1.2728	1.2848	32.75	35.50
1 1/2	12	1.5000	1.4459	1.3978	1.4098	36.00	38.50

TAPPING DRILL SIZES FOR FLUTELESS (THREAD FORMING) TAPS

METRIC COARSE

Tap Size x Pitch	Tapping Drill Size (mm)
M 2.0 x 0.40 mm	1.80
M 3.0 x 0.50 mm	2.80
M 3.5 x 0.60 mm	3.25
M 4.0 x 0.70 mm	3.70
M 4.5 x 0.75 mm	4.15
M 5.0 x 0.80 mm	4.65
M 6.0 x 1.00 mm	5.55
M 7.0 x 1.00 mm	6.55
M 8.0 x 1.25 mm	7.40
M 9.0 x 1.25 mm	8.40
M 10.0 x 1.50 mm	9.25
M 11.0 x 1.50 mm	10.25
M 12.0 x 1.75 mm	11.20
M 14.0 x 2.00 mm	13.10
M 16.0 x 2.00 mm	15.10
M 18.0 x 2.50 mm	16.90
M 20.0 x 2.50 mm	18.90

METRIC FINE & SPECIAL PITCHES

Tap Size x Pitch	Tapping Drill Size (mm)
M 5.0 x 0.50 mm	4.75
M 6.0 x 0.75 mm	5.65
M 7.0 x 0.75 mm	6.65
M 8.0 x 1.00 mm	7.55
M 9.0 x 1.00 mm	8.55
M 10.0 x 1.00 mm	9.55
M 10.0 x 1.25 mm	9.40
M 11.0 x 1.00 mm	10.55
M 12.0 x 1.00 mm	11.55
M 12.0 x 1.25 mm	11.40
M 12.0 x 1.50 mm	11.30
M 14.0 x 1.00 mm	13.55
M 14.0 x 1.25 mm	13.40
M 14.0 x 1.50 mm	13.30
M 16.0 x 1.00 mm	15.55
M 16.0 x 1.50 mm	15.30
M 18.0 x 1.50 mm	17.30

U.N.C.

Tap Size	Tapping Drill Size (mm)
No. 1	1.65 mm
No. 2	1.95 mm
No. 3	2.25 mm
No. 4	2.55 mm
No. 5	2.90 mm
No. 6	3.20 mm
No. 8	3.80 mm
No. 10	4.30 mm
No. 12	5.00 mm
1/4"	5.80 mm
5/16"	7.30 mm
3/8"	8.80 mm

U.N.F.

Tap Size	Tapping Drill Size (mm)
No. 0	1.40 mm
No. 1	1.70 mm
No. 2	2.00 mm
No. 3	2.30 mm
No. 4	2.60 mm
No. 5	2.90 mm
No. 6	3.20 mm
No. 8	3.80 mm
No. 10	4.50 mm
No. 12	5.10 mm
1/4"	5.90 mm
5/16"	7.50 mm
3/8"	9.00 mm

B.A.

0	5.60 mm
1	4.90 mm
2	4.40 mm
3	3.80 mm
4	3.30 mm
5	2.95 mm
6	2.60 mm
7	2.30 mm
8	2.00 mm
10	1.55 mm

B.S.W

1/8"	2.90 mm
3/16"	4.30 mm
1/4"	5.80 mm
5/16"	7.30 mm
3/8"	8.80 mm

B.S.F

3/16"	4.40 mm
7/32"	5.20 mm
1/4"	5.90 mm
5/16"	7.40 mm
3/8"	9.00 mm

Engineers Black Book - 2nd Edition

REMOVAL OF BROKEN TAPS

Removing a Broken Tap

Broken Taps that get lodged into a workpiece can be removed without damaging the component. Many methods are employed, the most common being :

- Using a Tap Extractor, e.g., WALTON®.
- Electrodischarge Machining (EDM) / (Spark Eroding).
- Using a Tap Disintegrator.
- Welding a Nut onto the protruding part of the Broken Tap.
- Drilling out the Broken Tap using a Solid Carbide Drill Bit.

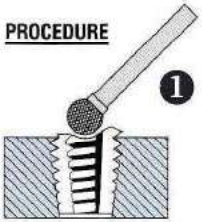
Drilling Out a Broken Tap using a Solid Carbide Screw (Tap) Drill

Broken Tap lodged in the Workpiece

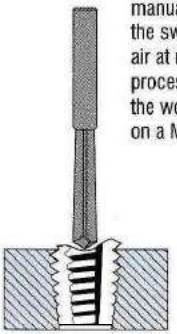
Solid Carbide Screw (Tap) Drill

This drill is specially designed for drilling out broken taps and other materials with hardness ≤ 72 Rc. Recommended drill speed : 1500 - 3000 rpm. No coolant necessary.

PROCEDURE



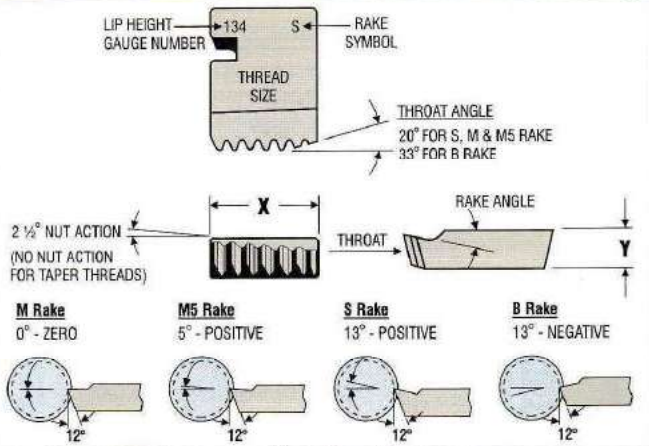
1. Using a Ball Nose Carbide Rotary Burr, grind a semi-circular indent into the core of the broken tap. This provides a centre-point (seat) for locating the Solid Carbide Screw (Tap) Drill bit and prevents it from wandering. This operation is very critical to the success of subsequent drilling.



2. Using a suitable diameter Solid Carbide Screw (Tap) Drill at a speed of 1500 to 3000 rpm and a steady and continuous manual feed, drill out the core of the broken tap. Clean out the swarf and any broken chips of the tap with compressed air at regular intervals during the drilling operation. This process should only be carried out using a rigid setup with the workpiece solidly clamped in a vice & preferably be done on a Milling/Drilling machine. No cutting fluid is required.

3. Using a Scriber or sharp instrument, remove the remaining pieces of the tap. Clean out the tapped hole with compressed air and retap the hole again.

COVENTRY/OSG STYLE CHASERS



Chaser Identification

Die Head Size	X	Y
1/4"	5/16"	5/32"
5/16"	7/16"	5/32"
1/2"	1/2"	1/4"
3/4"	3/4"	5/16"
1"	7/8"	3/8"
1 1/4"	1"	7/16"
1 1/2"	1 1/8"	1/2"
2"	1 1/2"	5/8"

Threading Speed (metres per minute)

Speed Symbol	Surface Speed for t.p.i.			
	3-7 tpi	8-15 tpi	16-24 tpi	25 tpi & finer
1	2.5	3	4.5	6
2	4.5	6	7.5	9
3	6	9	12	15
4	7.5	12	15	24
5	12	24	30	45
6	15	30	45	60

Material Rake And Speed Symbols

Material	Rake	Speed	Material	Rake	Speed
Aluminium	S	6	Gun Metal	M	5
Brass	S	5	High Tensile Steel	M5	1
Bronze, Manganese	M	5	Mild Steel	S	3
Bronze (phosphor)	M	5	Monel Metal	M5	1
Cast Iron (grey)	M	4	Nickel Steel	M5	2
Cast Iron (malleable)	S	3	Plastics (soft)	S	4
Copper	S (nitrided)	5	Plastics (hard)	S	5
Diecast	S	6	Stainless Steels	M5	1

Screw/Gauge Diameters for Self Tapping, Self Drilling, Wood & American Gauge Number Screws

Gauge No.	(inch)	(mm)	Nearest approx fraction size	Gauge No.	(inch)	(mm)	Nearest approx fraction size
0	.060"	1.52	1/16"	6 *	.138"	3.50	9/64"
1	.073"	1.85	5/64"	7	.151"	3.83	5/32"
2 *	.086"	2.18	3/32"	8 *	.164"	4.16	11/64"
3	.099"	2.51	3/32"	10 *	.190"	4.83	3/16"
4 *	.112"	2.84	7/64"	12	.216"	5.49	7/32"
5	.125"	3.17	1/8"	14	.242"	6.15	1/4"

* Preferred Sizes

DRILL SIZES FOR SCREW EXTRACTORS, WOOD SCREWS, SELF TAPPERS, BLIND RIVETS & LAG SCREWS

Recommended Drill Sizes for Standard Screw Extractors

Screw Extractor No.	Outside Dia. of Screw (mm)	Outside Dia. of Screw (inch)	Recommended Drill Size (mm)	Recommended Drill Size (inch)
1	M4 - M5	5/32 - 3/16	2.0	# 47
2	M6 - M7	7/32 - 1/4	2.8	# 35
3	M8 - M10	5/16 - 3/8	4.0	5/32"
4	M12 - M14	1/2 - 9/16	5.5	7/32"
5	M16 - M20	5/8 - 3/4	7.5	19/64"
6	M22 - M24	7/8 - 1	11.0	7/16"
7	M28 - M36	1 1/8 - 1 1/2	13.5	17/32"
8	M40 - M45	1 5/8 - 1 3/4	20.0	13/16"
9	M48 - M52	1 7/8 - 2 1/8	27.0	1 1/16"
10	M56 - M60	2 1/4 - 2 1/2	33.0	1 5/16"

Recommended Drill Sizes for Self Tapping Screws Type 'A'

Screw Size No.	Sheet Thickness (mm)	Drill Size (mm)
No. 4 (2.84 mm)	0.40	2.2
	0.55	2.2
	0.75	2.4
	0.90	2.4
	1.00	2.5
No. 6 (3.50 mm)	0.40	2.5
	0.55	2.5
	0.75	2.6
	0.90	2.6
	1.00	2.7
No. 8 (4.16 mm)	0.55	2.8
	0.75	2.9
	0.90	3.0
	1.00	3.1
	1.20	3.3
No. 10 (4.83 mm)	0.55	3.3
	0.75	3.3
	0.90	3.4
	1.00	3.5
	1.20	3.8

Recommended Drill Sizes for Wood Screws (For use on Hardwoods)

Wood Screw Gauge Size	Recommended Drill Size For Screw Shank (mm)	Recommended Drill Size For Screw Thread (mm)
2	2.0	1.2
3	2.4	1.6
4	2.8	1.6
5	3.2	2.0
6	3.6	2.0
7	4.0	2.4
8	4.4	2.4
9	4.8	2.8
12	5.6	3.6
14	6.4	4.0
16	7.2	4.4
18	8.0	4.8
20	8.8	5.6
22	9.8	6.0
24	10.5	6.4

Recommended Drill Sizes for Blind Rivets

Rivet Diameter	Drill Diameter (mm)	Drill Diameter (inch)
3/32"	2.45	# 40
7/64"	2.85	# 33
1/8"	3.3	# 30
5/32"	4.1	# 20
3/16"	4.9	# 10
7/32"	5.6	# 2
1/4"	6.5	F

Recommended Drill Sizes for Lag Screws

Size	For Screw Shank (mm)	For Screw Thread (mm)
1/4" (6mm)	7.5	4.5
5/16" (8mm)	9.0	6.0
3/8" (10mm)	10.5	7.0
7/16" (11mm)	12.0	8.5
1/2" (12mm)	13.5	9.5
5/8" (16mm)	17.5	12.5
3/4" (20mm)	21.0	15.0
7/8" (22mm)	23.5	17.5
1" (25mm)	27.0	20.0

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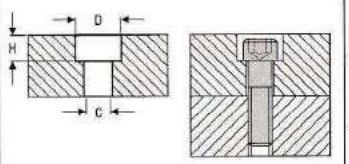
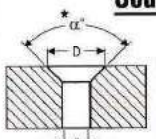
DIMENSIONS OF COUNTERBORING / COUNTERSINKING FOR SOCKET HEAD CAP SCREWS

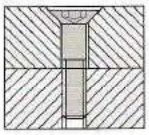
Counter Bore



Counterbore
Socket Head Cap Screw

Counter Sink





* NOTE :
METRIC $\alpha = 90°$
INCH $\alpha = 82°$

Countersink
Socket Head Cap Screw

Nominal Thread Size	Clearance For Thread 'C'	Clearance For Head 'D'	Depth 'H'	Clearance For Thread 'C'	Diameter of Countersink 'D'
			METRIC		Dimensions in mm
M3	3.4	6.0	3.4	3.4	6.7
M4	4.5	8.0	4.6	4.5	9.0
M5	5.5	10.0	5.7	5.5	11.2
M6	6.6	11.0	6.8	6.6	13.4
M8	9.0	15.0	9.0	9.0	17.9
M10	11.0	18.0	11.0	11.0	22.4
M12	14.0	20.0	13.0	14.0	26.9
M14	16.0	23.0	15.2	16.0	30.3
M16	18.0	26.0	17.5	18.0	33.6
M18	20.0	29.0	19.5	20.0	37.0
M20	22.0	32.0	21.5	22.0	40.3
M22	24.0	35.0	23.5		
M24	26.0	40.0	25.5		
M27	30.0	43.0	29.0		
M30	33.0	48.0	32.0		
			INCH		Dimensions in inches
No. 4	# 29	7/32"	0.125"	# 29	0.255"
No. 5	# 23	1/4"	0.140"	# 23	0.281"
No. 6	# 18	9/32"	0.160"	# 18	0.307"
No. 8	# 10	5/16"	0.185"	# 10	0.359"
No. 10	# 2	3/8"	0.215"	# 2	0.411"
1/4"	9/32"	7/16"	0.280"	9/32"	0.531"
5/16"	11/32"	17/32"	0.350"	11/32"	0.656"
3/8"	13/32"	5/8"	0.415"	13/32"	0.781"
7/16"	15/32"	23/32"	0.475"	15/32"	0.844"
1/2"	17/32"	13/16"	0.540"	17/32"	0.938"
5/8"	21/32"	1"	0.675"	21/32"	1.188"
3/4"	25/32"	1 3/16"	0.810"	25/32"	1.438"
7/8"	29/32"	1 3/8"	0.930"		
1"	1 1/32"	1 5/8"	1.050"		
1 1/4"	1 5/16"	2"	1.310"		

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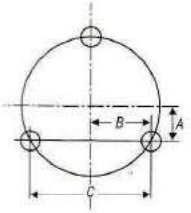
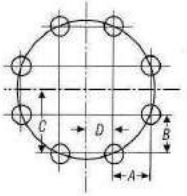
LOCATING HOLE COORDINATES FOR EQUALLY SPACED HOLES

Multiply values shown by diameter of pitch circle

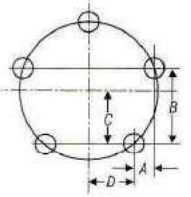
(Metric or Inch Units)



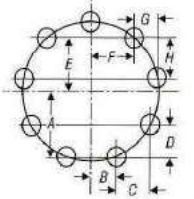
3-Hole
A = 0.25000
B = 0.43301
C = 0.86603



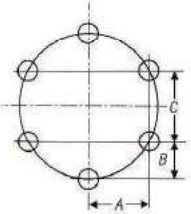
8-Hole
A = 0.27059
B = 0.27059
C = 0.46194
D = 0.19134



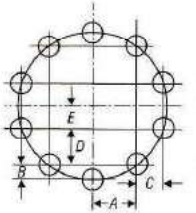
5-Hole
A = 0.18164
B = 0.55902
C = 0.40451
D = 0.29389



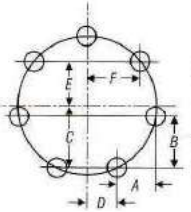
9-Hole
A = 0.46985
B = 0.17101
C = 0.26201
D = 0.21985
E = 0.38302
F = 0.32139
G = 0.17101
H = 0.29620



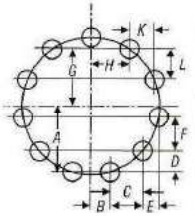
6-Hole
A = 0.43301
B = 0.25000
C = 0.50000



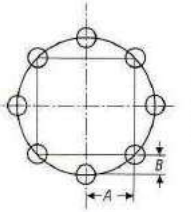
10-Hole
A = 0.29389
B = 0.09549
C = 0.18164
D = 0.25000
E = 0.15451



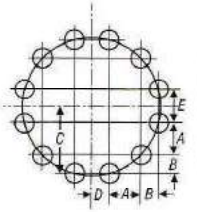
7-Hole
A = 0.27052
B = 0.33922
C = 0.45049
D = 0.21694
E = 0.31175
F = 0.39092



11-Hole
A = 0.47975
B = 0.14087
C = 0.23700
D = 0.15231
E = 0.11704
F = 0.25627
G = 0.42063
H = 0.27032
K = 0.18449
L = 0.21291



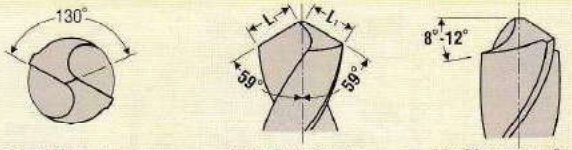
8-Hole
A = 0.35355
B = 0.14645



12-Hole
A = 0.22415
B = 0.12941
C = 0.48296
D = 0.12941
E = 0.25882

DRILL POINT SHARPENING

General Purpose 118° Point Angle



Chisel Edge Angle
The correct angle between the line across the dead centre and the cutting lip must be maintained.

Drill Point Angle
It is vitally important that both lips should be identical in length and angle to the drill axis.

Lip Clearance Angle
The clearance behind the cutting edges (lips) must be greater than the rate of penetration.

Web Thinning
The web thickness gradually increases after the drill has been reground several times. It is therefore recommended that the original web thickness be maintained

RECOMMENDED WEB THICKNESS		
Diameter of drill		Web thickness
(mm)	(inch)	% of diameter
3	1/8"	20 %
6	1/4"	17 %
13	1/2"	14 %
25	1"	12 %
> 25	> 1"	11 %

Hints for Hand Grinding Twist Drills

The periphery of the wheel should be used for roughing-out of the drill point if much metal must be ground away.

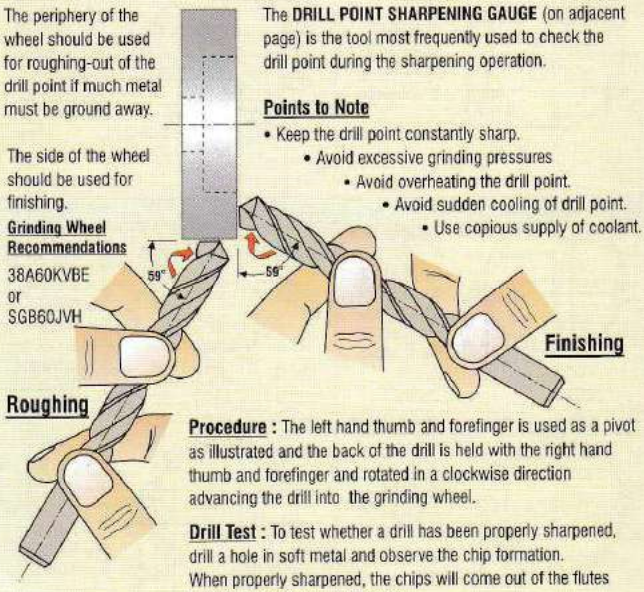
The side of the wheel should be used for finishing.

Grinding Wheel Recommendations
38A60KVBE
or
SGB60JVH

The **DRILL POINT SHARPENING GAUGE** (on adjacent page) is the tool most frequently used to check the drill point during the sharpening operation.

Points to Note

- Keep the drill point constantly sharp.
- Avoid excessive grinding pressures
- Avoid overheating the drill point.
- Avoid sudden cooling of drill point.
- Use copious supply of coolant.

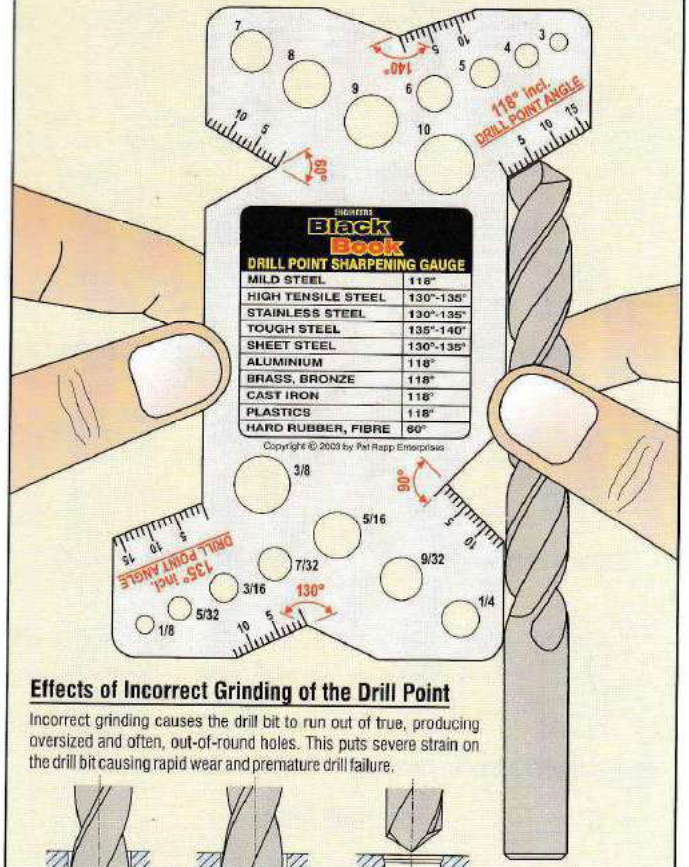


Procedure : The left hand thumb and forefinger is used as a pivot as illustrated and the back of the drill is held with the right hand thumb and forefinger and rotated in a clockwise direction advancing the drill into the grinding wheel.

Drill Test : To test whether a drill has been properly sharpened, drill a hole in soft metal and observe the chip formation. When properly sharpened, the chips will come out of the flutes in curled spirals of equal lengths.

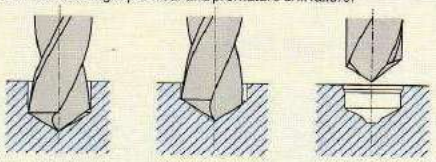
DRILL POINT SHARPENING GAUGE & EFFECTS OF INCORRECT GRINDING

Drill Point Sharpening Gauge



Effects of Incorrect Grinding of the Drill Point

Incorrect grinding causes the drill bit to run out of true, producing oversized and often, out-of-round holes. This puts severe strain on the drill bit causing rapid wear and premature drill failure.



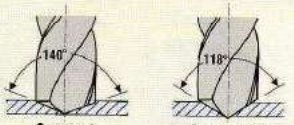
Lips of **EQUAL** lengths but **UNEQUAL** angles.

Lips of **UNEQUAL** lengths but **EQUAL** angles.

Lips of **UNEQUAL** lengths and **UNEQUAL** angles.

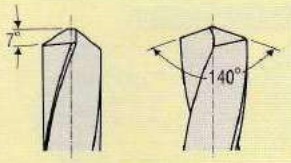
Drilling Thin Metal Sections

The point of the drill must be ground so that the outer corners are cutting before the points break through.

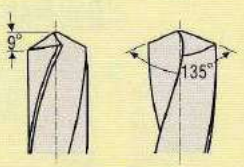


Correct **Incorrect**

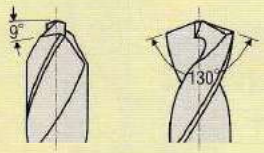
DRILL POINT GEOMETRY FOR VARIOUS MATERIALS



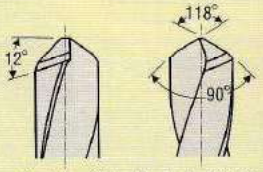
Tough Steels



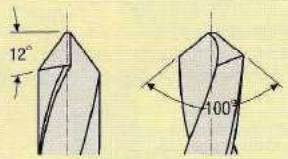
Stainless Steels



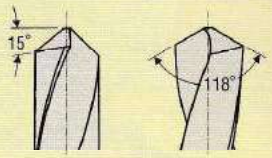
Deep Hole Drilling



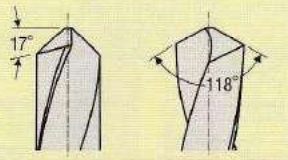
Cast Iron (Double-Angle Point)



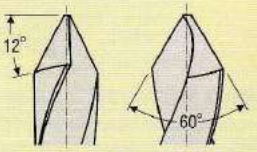
Copper & Some Copper Alloys



Aluminium, Brass & Soft Bronze

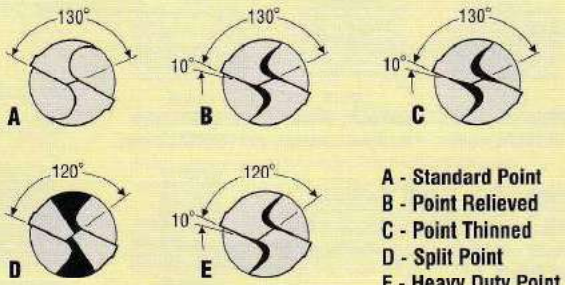


Bakelite, Plastics & Moulded Materials



Wood, Hard Rubber & Fibre

Drill Point Styles



A - Standard Point
B - Point Relieved
C - Point Thinned
D - Split Point
E - Heavy Duty Point

Engineers Black Book - 2nd Edition

SPEEDS & FEEDS FOR HIGH SPEED STEEL TWIST DRILLS

Drill Diameter (mm)	Drill Diameter (inch)	Stainless Steel	Tool Steel	Cast Iron	Malleable Iron	Medium Carbon Steel	Free Cutting Steel	Alum. Brass	Wood Plastic
		Work Material							
		Cutting Speed : Metres per minute							
		12	18	24	27	30	43	61	91
		Cutting Speed : Feet per minute							
		40	60	80	90	100	140	200	300
		Spindle Speed RPM							
1.5	1/16	2445	3667	4889	5500	6112	8556	12223	18335
2.5	3/32	1620	2445	3259	3667	4074	5704	8149	12223
3	1/8	1222	1833	2445	2750	3056	4278	6112	9167
4	5/32	978	1467	1956	2200	2445	3422	4889	7334
5	3/16	815	1222	1630	1833	2037	2852	4074	6112
6	1/4	654	982	1309	1473	1637	2292	3274	4911
7	9/32	543	815	1086	1222	1358	1901	2716	4074
8	5/16	489	733	978	1100	1222	1711	2445	3667
9	11/32	448	672	896	1008	1120	1568	2241	3361
10	3/8	407	611	815	917	1019	1426	2037	3056
11	7/16	349	524	698	786	873	1222	1746	2619
13	1/2	306	458	611	688	764	1070	1528	2292
14	9/16	272	407	543	611	679	951	1358	2037
16	5/8	244	367	489	550	611	856	1222	1833
18	23/32	222	333	444	500	556	778	1111	1667
19	3/4	204	306	407	458	509	713	1019	1528
20	25/32	189	224	378	425	473	662	946	1419
22	7/8	175	262	349	393	437	611	873	1310
25	1	153	229	306	344	382	535	764	1146
28	1 1/8	136	204	272	306	340	475	679	1019
32	1 1/4	122	183	244	275	306	428	611	917
35	1 3/8	111	167	222	250	278	389	556	833
38	1 1/2	102	153	204	229	255	357	509	764
41	1 5/8	94	141	188	212	235	329	470	705
44	1 3/4	87	131	175	196	218	306	437	655
47	1 7/8	81	122	163	183	204	285	407	611
50	2	76	115	153	172	191	267	382	573
57	2 1/4	68	102	136	153	170	238	340	509
63	2 1/2	61	92	122	138	153	214	306	458
70	2 3/4	56	83	111	125	139	194	278	417
76	3	51	76	102	115	127	178	255	382

Recommended Feeds for Various Drill Diameters			
Diameter of Drill		Feed per Revolution	
(mm)	(inch)	(mm)	(inch)
3	1/8	.02 - .10	.001 - .003
6	1/4	.05 - .15	.002 - .006
13	1/2	.10 - .25	.004 - .010
25	1	.20 - 40	.007 - .015
> 25	> 1	.40 - .65	.015 - .025

Note : The information on this page is intended as a general guide only. Figures will vary with grades of material used.

It is best to start with a moderate speed and feed, increasing either one, or both, after observing the cutting action and condition of the drill bit.

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SPEEDS AND FEEDS FOR STANDARD SOLID CARBIDE DRILLS

Types of Solid Carbide Drills

Straight Flute Drill

Strong construction with 140° drill point angle suitable for hardened & difficult to machine materials. Hole depth should not exceed 2 x dia.

Slow Spiral Drill - 15°-20°

Designed to drill hardened and gummy materials and High-temperature Alloys. Also recommended for Stainless Steel, Tool Steel & Titanium-Nickel Alloys.

Twist Drill - 25°-30°

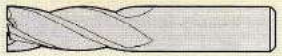
2 & 3 Flute general purpose drill ideal for low-tensile & non-ferrous materials such as high Si Aluminium, Bronze, Masonite & Resin/ Fibreglass Laminates.

Material	Speed (m/min)	Solid Carbide Drill Diameter								
		rpm mm/r	1.5 mm	3.0 mm	4.0 mm	5.0 mm	6.0 mm	8.0 mm	10.0 mm	12.0 mm
Aluminium/ Al Alloys	75-80	rpm	15920	7960	5970	4770	3980	2980	2390	1990
		feed	0.025	0.075	0.10	0.15	0.18	0.21	0.25	0.390
Brass	75	rpm	15920	7960	5970	4770	3980	2980	2390	1990
		feed	0.015	0.05	0.06	0.07	0.075	0.08	0.09	0.10
Bronze/Copper	45	rpm	9550	4770	3580	2930	2860	1790	1430	1190
		feed	0.015	0.05	0.06	0.07	0.075	0.08	0.09	0.10
Cast Iron (Soft)	76-81	rpm	16130	8060	6050	4840	4030	3020	2420	2020
		feed	0.025	0.075	0.10	0.12	0.15	0.20	0.25	0.30
Cast Iron (Hard)	46-51	rpm	9760	4880	3660	2930	2440	1830	1460	1220
		feed	0.013	0.05	0.06	0.08	0.10	0.13	0.15	0.18
Plastics/ Composites	46-51	rpm	9760	4880	3660	2930	2440	1830	1460	1220
		feed	0.025	0.05	0.07	0.09	0.10	0.11	0.12	0.13
Mild Steel	30-35	rpm	6370	3180	2390	1910	1590	1190	950	800
		feed	0.025	0.05	0.06	0.08	0.10	0.13	0.15	0.18
Carbon Steel	69-74	rpm	14640	7320	5490	4390	3660	2750	2200	1830
		feed	0.025	0.05	0.06	0.07	0.075	0.09	0.012	0.015
Alloy Steel/ High Tensile	26-31	rpm	5520	2760	2070	1660	1380	1030	830	690
		feed	0.013	0.018	0.02	0.02	0.025	0.025	0.025	0.025
Hardened/Tool Steel	15-20	rpm	3180	1590	1190	950	800	600	480	400
		feed	0.025	0.05	0.06	0.07	0.075	0.09	0.012	0.15
Stainless Steel/ Free M/C	30-35	rpm	6370	3180	2390	1910	1590	1190	950	800
		feed	0.025	0.075	0.09	0.10	0.13	0.15	0.18	0.20
Stainless Steel/ Work Hardened	23-28	rpm	4880	2440	1830	1460	1220	920	730	610
		feed	0.013	0.05	0.07	0.09	0.10	0.12	0.13	0.15

NOTE : To enhance Hole Quality and Tool Life, the use of copious quantity of coolant is recommended, particularly directed at the drill point to prevent chipping or flaking of the Carbide cutting edge.

TYPES & APPLICATIONS OF HIGH SPEED STEEL END MILLS

Standard 30° Spiral

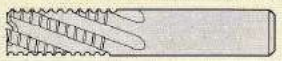


Suitable for both Finishing and Roughing operations on Mild Steel, Heat Treatable and Structural Steels with tensile strengths < 1000 N/mm². This cutter can also be used for short chipping Non-Ferrous metals. Usually comes with a variety of surface coatings.

Round Knuckle (Sinusoidal) Teeth Roughing

Suitable for maximum Roughing where rapid metal removal is the prime requisite. The cutting action produces short chips with excellent chip removal. As this cutter is mainly designed for rapid metal removal, additional finishing operations are necessary.

Flat Knuckle Teeth Roughing



Suitable for Medium Roughing operations where rapid metal removal is the prime requisite. This cutter produces a finish that is generally better than the Round Knuckle Teeth cutter, yet requires additional finishing operations.

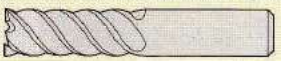
Fine Pitch Knuckle Teeth Roughing

Suitable for Medium Roughing applications on high tensile material where rapid metal removal plus surface finish are the prime requisites. It produces a finish that is better than both of the above roughing cutters and generally no additional finishing is required.

40° Quick Spiral

Suitable for Roughing and Finishing Soft, Tough and Long-Chipping materials. This cutter produces an excellent surface finish with no additional finishing required. Comes in a variety of surface coatings.

45°- 55° Extremely Quick Spiral



Suitable for Finishing High Tensile materials up to 1200 N/mm² as well as Titanium, Nodular Cast Iron and difficult to machine materials. Comes in a variety of surface coatings.

CONVERSION TABLE
SURFACE / CUTTING SPEED TO R.P.M.

Diameter (mm)	Diameter (inch)	Surface / Cutting Speed : Metres per minute: 3	5	8	10	15	20	25	30	35
		Surface / Cutting Speed : Feet per minute: 10	16	26	33	49	66	82	98	115
		Spindle Speed (RPM)								
2		477	795	1272	1590	2386	3181	3976	4771	5566
3		318	530	848	1060	1590	2121	2651	3181	3711
	1/8"	300	500	800	1000	1200	1500	2501	3001	3501
4		239	398	636	795	1193	1590	1988	2386	2783
	3/16"	200	334	535	668	1002	1336	1671	2005	2339
5		191	318	509	636	954	1272	1590	1908	2227
6		159	265	424	530	795	1060	1325	1590	1855
	1/4"	150	250	401	501	751	1002	1252	1503	1753
	5/16"	120	200	320	401	601	801	1002	1202	1402
8		119	199	318	398	596	795	994	1193	1392
	3/8"	100	167	267	334	501	668	834	1001	1168
10		95	159	254	318	477	636	795	954	1113
	7/16"	86	143	229	286	429	573	716	859	1002
12		80	133	212	265	398	530	663	795	928
	1/2"	75	125	200	250	376	501	626	751	877
14		68	114	182	227	341	454	568	682	795
	9/16"	67	111	178	223	334	445	556	668	779
	5/8"	60	100	160	200	300	401	501	601	701
16		60	99	159	199	298	398	497	596	696
18		53	88	141	171	265	353	442	530	618
	3/4"	50	83	134	167	250	334	417	501	584
20		48	80	127	159	239	318	398	477	557
22		43	72	116	145	217	289	361	434	506
	7/8"	43	72	114	143	215	286	358	429	501
24		40	66	106	133	199	265	331	398	464
25		38	64	102	127	191	254	318	382	445
	1"	38	63	100	125	188	250	313	376	438
30		32	53	85	105	159	212	265	318	371
	1 1/4"	30	50	80	100	150	200	250	300	350
	1 1/2"	25	41	67	83	125	167	208	250	292
40		24	40	63	79	119	159	199	238	278
	1 3/4"	21	36	57	71	107	143	179	214	250
50		19	32	51	63	95	127	159	191	222
	2"	19	31	50	62	94	125	156	188	219
75		13	21	34	42	64	85	106	127	148
	3"	13	21	33	42	63	83	104	125	146
100		9	16	25	32	48	63	79	95	111
	4"	9	16	25	31	47	62	78	94	110
200		5	8	13	17	24	32	40	48	56
	8"	5	8	12	16	23	31	39	47	55
300		3	5	8	10	16	21	26	31	37
	12"	3	5	8	10	16	21	26	31	37

NOTE : R.P.M. for Surface / Cutting Speeds not given, can be obtained by simple addition or subtraction. Example :

120 m/min = 100 + 20 = 3183 R.P.M. + 636 R.P.M. = 3819 R.P.M. (for 10mm dia.)

180 ft/min = 262 - 82 = 2004 R.P.M. - 626 R.P.M. = 1378 R.P.M. (for 1/2"dia.)

CONVERSION TABLE
SURFACE / CUTTING SPEED TO R.P.M.

Diameter (mm)	Diameter (inch)	Surface / Cutting Speed : Metres per minute: 40	45	50	60	70	80	90	100	200
		Surface / Cutting Speed : Feet per minute: 131	148	164	197	230	262	295	328	656
		Spindle Speed (RPM)								
2		6362	7157	7952	9542	11133	12723	14314	15904	31808
3		4241	4771	5301	6362	7422	8482	9543	10603	21206
	1/8"	4001	4501	5001	6002	7002	8002	9003	10003	20006
4		3181	3578	3976	4771	5566	6362	7157	7952	15904
	3/16"	2673	3007	3341	4009	4678	5346	6014	6682	13364
5		2546	2865	3183	3820	4456	5093	5730	6366	12732
6		2122	2387	2653	3183	3714	4244	4775	5305	10610
	1/4"	2004	2254	2505	3005	3506	4007	4508	5009	10018
	5/16"	1602	1803	2003	2404	2804	3205	3606	4006	8012
8		1592	1790	1989	2387	2785	3183	3581	3979	7958
	3/8"	1335	1502	1669	2003	2336	2670	3004	3338	6676
10		1273	1432	1592	1910	2228	2546	2865	3183	6366
	7/16"	1145	1288	1432	1718	2004	2290	2577	2863	5726
12		1061	1194	1326	1592	1857	2122	2387	2653	5305
	1/2"	1002	1127	1252	1503	1753	2004	2255	2505	5010
14		909	1022	1136	1363	1590	1818	2045	2272	4544
	9/16"	890	1002	1113	1336	1558	1781	2004	2226	4452
	5/8"	801	901	1002	1202	1402	1602	1803	2003	4006
16		795	895	995	1194	1393	1591	1790	1989	3979
18		707	795	884	1060	1237	1414	1590	1767	3534
	3/4"	668	751	835	1002	1169	1336	1503	1670	3340
20		637	716	796	955	1114	1273	1432	1592	3183
22		578	651	723	867	1012	1157	1301	1446	2892
	7/8"	572	644	716	859	1002	1145	1288	1431	2862
24		530	596	663	795	928	1060	1192	1325	2650
25		509	573	637	764	891	1019	1146	1273	2546
	1"	501	564	626	751	877	1002	1127	1252	2504
30		424	477	530	637	743	849	955	1061	2122
	1 1/4"	400	450	501	601	701	801	901	1001	2003
	1 1/2"	334	375	417	501	584	668	751	835	1670
40		318	358	398	477	557	637	716	796	1592
	1 3/4"	286	322	358	429	501	572	644	715	1431
50		255	286	318	382	446	509	573	637	1273
	2"	250	282	313	375	438	501	563	626	1252
75		170	191	212	255	297	340	382	424	849
	3"	167	188	209	250	292	334	376	417	835
100		127	143	159	191	223	255	286	318	637
	4"	125	141	156	187	219	250	281	313	626
200		64	72	80	95	111	127	143	159	318
	8"	63	70	78	94	110	125	141	156	313
300		42	48	53	64	74	85	96	106	212
	12"	41	47	52	63	73	83	94	104	209

To calculate RPM in m/min = $\frac{1000 \times Vc}{\pi \times D}$

Where Vc = surface speed (m/min), D = diameter

To calculate RPM in ft/min = $\frac{SFM \times 3.82}{D}$

Where SFM = surface speed (ft/min), D = diameter

HOLE SAWS
RECOMMENDED CUTTING SPEEDS

RPM for High Speed Steel Hole Saws

Uses : Mild Steel, Cast Iron, Tool Steel, Stainless Steel, Brass, Aluminium, Wood, etc.

NOTE:

- Use Coolant when cutting Metals.
- Apply sufficient pressure to ensure that the Hole Saw cuts and does not rub.
- When cutting wood, finish off the operation from the reverse side to avoid splinters.

Dimension		Recommended Speed (rpm)					
(mm)	(inch)	Mild Steel	Cast Iron	Tool Steel Stainless	Brass	Aluminium	Wood
14	9/16"	580	400	300	790	900	3000
16	5/8"	550	365	275	730	825	3000
19	3/4"	460	300	230	600	690	3000
20	-	440	290	220	580	660	3000
21	13/16"	425	280	210	560	635	3000
22	7/8"	390	260	195	520	585	3000
25	1"	350	235	175	470	525	2700
29	1 1/8"	300	200	150	400	450	2700
30	-	285	190	145	380	425	2400
32	1 1/4"	275	180	140	380	410	2400
35	1 3/8"	250	165	125	330	375	2400
38	1 1/2"	230	150	115	300	345	2400
40	-	220	145	110	290	330	2100
41	1 5/8"	210	140	105	280	315	2100
44	1 3/4"	195	130	95	260	295	2100
48	1 7/8"	180	120	90	240	270	2100
51	2"	170	115	85	230	255	2000
57	2 1/4"	150	100	75	200	225	2000
60	2 3/8"	140	95	70	190	220	2000
64	2 1/2"	135	90	65	180	205	1800
70	2 3/4"	125	80	60	160	185	1800
76	3"	115	75	55	150	170	1500
83	3 1/4"	105	70	50	40	155	1500
89	3 1/2"	95	65	45	130	145	1200
102	4"	85	55	40	110	130	1000
127	5"	65	45	30	90	90	800
152	6"	55	35	25	75	75	800

HOLE SAWS
RECOMMENDED CUTTING SPEEDS

RPM for Carbide Tipped Hole Saws.

Uses : Aluminium, Brass, Cast Iron, Mild Steel, Wood, Plastics, etc.

Hole Saw Diameter		Aluminium	Brass	Cast Iron	Mild Steel	Wood & Plastics
(mm)	(inch)					
14-25	9/16-1"	850-600	750-550	375-300	550-400	3000-2500
25-50	1-2"	600-300	550-250	300-125	400-200	2500-2000
50-75	2-3"	300-200	250-175	125-75	200-125	2000-1500
75-100	3-4"	200-150	175-125	75-50	125-100	1500-1000
100-200	4-8"	150-100	125-75	50-25	100-50	1000-500

RPM for Diamond Edged Hole Saws

Uses : Asbestos/Substitutes, Ceramics, Marble, Stone, etc.

Hole Saw Diameter		Asbestos / Substitutes	Ceramics / Stone	Reinfo- Plastics, Fibreglass
(mm)	(inch)			
19-25	3/4-1"	700-350	500-250	1000-500
25-50	1-2"	350-175	250-100	500-250
50-75	2-3"	175-100	100-75	250-150
75-125	3-5"	100-50	75-40	150-75
125-150	5-6"	50-25	40-20	75-50

RPM for Carbide Grit Hole Saws

Uses : Asbestos/Substitutes, Ceramic Tiles, Reinforced Plastics, etc.

Hole Saw Diameter		Asbestos / Substitutes	Ceramic Tiles	Reinfo- Plastics, Fibreglass
(mm)	(inch)			
19-25	3/4-1"	700-350	500-250	1000-500
25-50	1-2"	350-175	250-100	500-250
50-75	2-3"	175-100	100-75	250-150
75-125	3-5"	100-50	75-40	150-75
125-150	5-6"	50-25	40-20	75-50

NOTE : The above information is intended as a general guide only. Speeds will vary with grades of materials used. It is best to start with a slow speed and increase the speed after observing the cutting action and condition of the Hole Saw.

Coolant should be used, especially when cutting metals and ceramics. Always use enough pressure to ensure that the Hole Saw cuts and does not rub the material being cut.

HACKSAW AND POWERSAW BLADES SELECTION AND APPLICATIONS

Hacksaw Blades

Hacksaw blade types :

- **Standard** (All hard / Flexible) – High Speed Steel,
- **Bi-metal** (Flexible) – High Speed Steel,
- **Cobalt** (Flexible) – Cobalt High Speed Steel
- **Low-Alloy** (Flexible) – Carbon Steel

All hard blades are breakable but tend to cut straighter than flexible blades.

Flexible blades are shatter-proof and are designed for cutting odd shapes.

General Recommendations for tooth sizes :

18 teeth per inch : For cutting solid sections of Steel and Non-Ferrous Metals over 13mm (1/2").

24 teeth per inch : For cutting solid sections of Steel between 3 mm (1/8") and 13mm (1/2"), as well as Medium Tubing and Medium Angle-iron.

32 teeth per inch : For cutting sections less than 3 mm (1/8") such as Thin Wall Tubing, Sheet Steel and Light Angle-iron.

Powersaw Blades

Power blades types :

- Standard – All-Hard High Speed Steel
- Bi-metal – High Speed Steel

These blades are designed for use in a Power Hacksaw Machine and work in the direction of the down stroke.

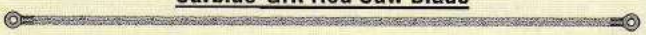
General Recommendations for tooth sizes :

6 teeth per inch : For cutting large solid sections of soft materials and steels over 50mm (2").

10 teeth per inch : For cutting medium solid sections of soft materials and all types of other materials over 25mm (1").

14 teeth per inch : For cutting thin section of all types of materials such as pipe, tubing, light angle iron and solid metal sections under 13mm (1/2").

Carbide-Grit Rod Saw Blade



This saw blade is manufactured using a 3 mm (1/8") diameter, high tensile, flexible cable onto which carbide particle grit is bonded. It fits into a standard hacksaw frame and is specifically designed for cutting odd shapes in Ceramic Tiles, Reinforced Plastics & Composites.

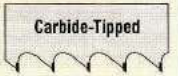
Engineers Black Book - 2nd Edition

BANDSAW BLADES TYPES AND APPLICATIONS

Bandsaw Blades

Bi-Metal Blade : This blade is made of a thin strip of HSS welded on to a spring steel backing. The result is a durable blade that can withstand heat generated when cutting steels.
Uses : Mild / Carbon / Alloy / Tool and Stainless steels.

Carbide-Tipped Blade : This blade is made of Solid Carbide Tips welded on to a high-strength spring steel alloy backing. The very hard cutting edges of the Carbide tips ensure extended durability.
Uses : Alloy steels, Stainless steels, Nickel and Titanium-based alloys.



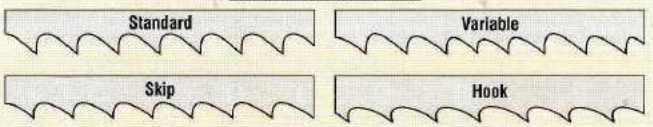
Carbide-Grit Blade : This blade is made of Tungsten carbide particle grit bonded on to a spring steel backing. This blade performs well on non-metals.
Uses : Fibre glass and Composite materials.

Diamond-Edge Blade : This blade is made of Industrial diamond grit bonded to a spring steel alloy backing. This blade performs well on abrasive non-metals..
Uses : Marble, Granite and Ceramics.

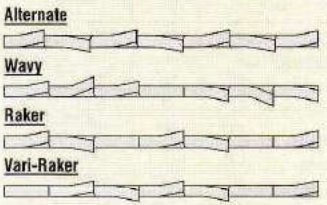
Carbon Flex-Back Blade : This blade is made of one-piece Carbon steel that is hardened and tempered and is especially designed for cutting curves.
Uses : Wood, Plastics and Non-ferrous materials.

Carbon Hard-Back Blade : This blade is made of one-piece Carbon steel that is hardened and tempered. The stiffer backing material ensures straighter cutting and resists swaging.
Uses : Wood, Plastics and Non-ferrous materials.

Standard Tooth Forms



Standard Tooth Set



Alternate sequence - Every tooth set in an alternating sequence.

Groups of teeth are set to each side in a controlled pattern

Three tooth sequence - Left, Right, Straight Uniform set angle

Multi-tooth sequence depending on tooth pitch. Varying set angles

Maximum Blade Width Selection Chart for Radius Cutting

Maximum Blade Width (mm)	3	5	6	10	13	16	20	25
Minimum Cutting Radius (mm)	3	8	15	40	65	100	140	175

SHARPENING OF HIGH SPEED STEEL TOOL BITS

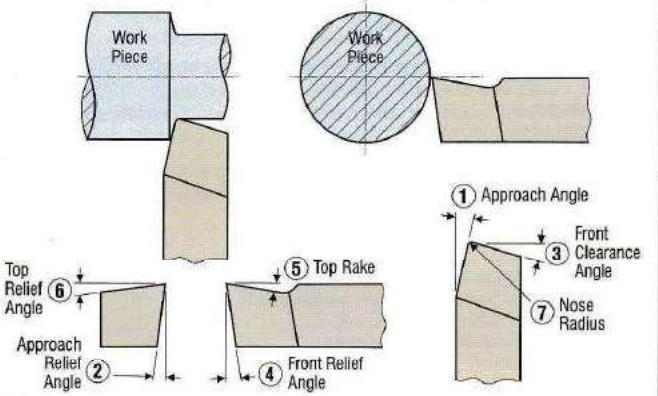
Hints for Sharpening HSS Tool Bits

Proper sharpening of HSS Tool Bits results in increased production, better surface finish and accuracy of work. The tool bit should be roughed out using an aluminium oxide wheel of 46-60 grit followed by a wheel of finer grit to secure a keen edge.

The main steels used for HSS Tool Bits are:

M2 - Tungsten Molybdenum grade HSS, which has very good toughness and wear resistance properties and recommended for machining low alloy & free machining steels and most non-ferrous materials.

M42 - Tungsten-Molybdenum-Cobalt grade HSS, possessing excellent toughness and greater resistance to abrasion with a high "red hardness". Tool Bits made from this material can withstand higher cutting speeds and are suited to machining tough steels.



NOTE : A coolant must be used to minimise temperature build-up. An overheated tool bit should never be plunged into water as this will produce hair-line cracks, resulting in chipping of the cutting edge.

Material to be Machined	Numerical Order for Grinding HSS Toolbits						
	① Approach ∠	② Approach Relief ∠	③ Front Cl. ∠	④ Front Relief ∠	⑤ Top Rake ∠	⑥ Top Relief ∠	⑦ Nose Radius
Aluminium	Normally 15° Varied to suit work profile.	12°	Normally 15° Varied to suit work profile.	8°	35°	15°	To suit work profile. Larger radii extends tool life.
Brass-Bronze		10°		8°	0°	5°	
Cast Iron		10°		8°	5°	12°	
Copper		14°		12°	16°	20°	
Fibre		15°		12°	0°	0°	
Monel		15°		13°	8°	14°	
Nickel		15°		13°	8°	14°	
Mild Steel		12°		8°	16°	14°	
Med. Carbon Steel		10°		8°	12°	14°	
High Tensile Steel		10°		8°	8°	12°	
Stainless Steel		10°		8°	10°	15°	
Thermoplastics		20°		15°	20°	20°	
Moulded Materials		12°		10°	10°	14°	

COOLANTS / LUBRICANTS / CUTTING FLUIDS USED IN MACHINING

It is advisable to always use a Coolant when cutting / machining metals.

Coolants :

- Dissipate heat from both the tool & workpiece, permitting faster cutting speeds.
- Act as a lubricant between the tool and the workpiece, preventing heat build-up.
- Significantly extend the life of the cutting tool by reducing its wear.
- Remove swarf away from the cutting edge.
- Act as a short-term rust preventative.

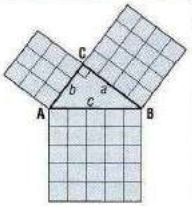
The selection of the most appropriate coolant is important to ensure efficiency of the cutting tool. The following is a general guide for day-to-day workshop machining requirements. For long-run production jobs, it is advisable to seek the assistance of Coolant Manufacturers.

Material	General Cutting Fluid Recommendations for Drilling, Milling, Reaming, Tapping and Turning.
Aluminium	A mixture of Kerosene and Lard Oil is very effective as a coolant and lubricant in most machining operations. Soluble Oil is used as an alternative. In Rough Machining applications, where excessive heat is produced, a Soluble Oil mixture containing at least 90 per cent water may be used to dissipate the heat. Sulphurised Oils should be avoided for machining Aluminium as this may result in discoloration of the metal.
Brass	Brass is normally machined Dry. However, Soluble/Lard Oil is commonly used for Tapping.
Bronze	Soluble Oil/Mineral Oil is effective in machining Bronze.
Cast Iron	Cast Iron is usually machined Dry or with an Air blast. However, Sulphurized Oil/Mineral Lard Oil is used for Tapping. To avoid excessive metal dust, Soluble Oil or low viscosity Mineral Oil may be used.
Cast Steel	Soluble Oil is very effective as a Cutting fluid.
Copper	Soluble Oil is very effective for machining copper. However Lard Oil is preferable for Tapping.
Magnesium	Magnesium is machined Dry as coolants containing water could react with Magnesium chips forming hydrogen gas that could pose a fire danger. When a cutting fluid is needed, Lard Oil may be used.
Malleable Iron	Malleable Iron is generally machined Dry. However, Lard Oil is preferred for Tapping.
Nickel	A Synthetic Oil with high pressure additives is recommended.
Plastics	Plastics are usually machined Dry. However, a medium Sulphurised Mineral Oil may be used.
Stainless Steel	A Semi-Synthetic cutting fluid with high pressure additives is recommended. For Tapping, a Lard Oil / Mineral Oil mixture is effective.
Alloy Steel	A light Soluble Oil is recommended. However, for Tapping applications, a mixture of Sulphur-based Oil with Mineral Oil is effective.
Mild Steel	General purpose Soluble Oil is recommended.
Tool Steel	A Semi-synthetic Oil with pressure additives is recommended. For Tapping, a mixture of Lard Oil and Mineral Oil is effective.
Titanium	A High-Soluble Synthetic Oil is recommended.
Zinc Alloys	A mixture of Kerosene and Lard Oil is effective.

NOTE: When using Fluteless Taps, it is advisable to use a straight Semi-Synthetic Oil with an extreme high pressure additive as a lubricant rather than a coolant.

TRIGNOMETRY
FORMULAE FOR SOLUTION OF TRIANGLES

The Pythagoras Theorem



In a right-angle triangle ABC, the square of the hypotenuse is equal to the sum of the squares of the other two sides.

c = *Hypotenuse*; a & b = *the other two sides*.

$$c^2 = a^2 + b^2$$

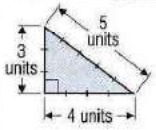
$$\therefore\ c = \sqrt{a^2 + b^2} \qquad a = \sqrt{c^2 - b^2} \qquad b = \sqrt{c^2 - a^2}$$

Example : *To find c when a = 8 cm and b = 6 cm.*

$$c^2 = a^2 + b^2 \quad \therefore\ c = \sqrt{a^2 + b^2} = \sqrt{8^2 + 6^2} = \sqrt{64 + 36} = \sqrt{100} = 10\ cm.$$

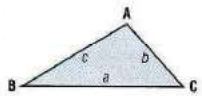
The 3-4-5 Rule

To construct a right-angle triangle without measuring instruments, using the 3-4-5 rule.



- Choose any suitable unit of measure (length).
- Construct a △ whose sides measure 3 units, 4 units, 5 units.
- The angle opposite the 5 units is a right angle.

Formulae for the solution of OBLIQUE ANGLE TRIANGLES

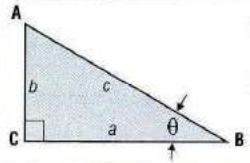


The Sine rule : $\dfrac{a}{\text{Sin A}} = \dfrac{b}{\text{Sin B}} = \dfrac{c}{\text{Sin C}}$

The Cosine rule :

$$a^2 = b^2 + c^2 - 2bc\ \text{CosA}$$
$$b^2 = a^2 + c^2 - 2ac\ \text{CosB}$$
$$c^2 = a^2 + b^2 - 2ab\ \text{CosC}$$

Formulae for the solution of RIGHT ANGLE TRIANGLES



$$\text{Sin}\,\theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{b}{c} \qquad \text{Cotan}\,\theta = \frac{\text{adjacent}}{\text{opposite}} = \frac{a}{b}$$

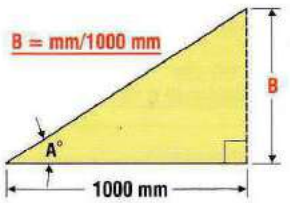
$$\text{Cos}\,\theta = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{a}{c} \qquad \text{Cosec}\,\theta = \frac{\text{hypotenuse}}{\text{opposite}} = \frac{c}{b}$$

$$\text{Tan}\,\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{b}{a} \qquad \text{Sec}\,\theta = \frac{\text{hypotenuse}}{\text{adjacent}} = \frac{c}{a}$$

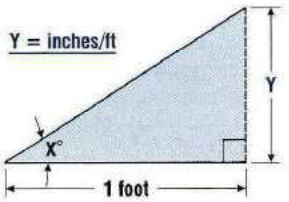
Parts Given	Parts to be Found				
	A	B	a	b	c
a & c	$\sin A = \frac{a}{c}$	$\cos B = \frac{a}{c}$		$b = \sqrt{c^2 - a^2}$	
a & b	$\tan A = \frac{a}{b}$	$\tan B = \frac{b}{a}$			$c = \sqrt{a^2 + b^2}$
c & b	$\cos A = \frac{b}{c}$	$\sin B = \frac{b}{c}$	$a = \sqrt{c^2 - b^2}$		
A & a		$B = 90° - A$		$b = \frac{a}{\text{Tan A}}$	$c = \frac{a}{\sin A}$
A & b		$B = 90° - A$	$a = b \times \tan A$		$c = \frac{b}{\cos A}$
A & c		$B = 90° - A$	$a = c \times \sin A$	$b = c \times \cos A$	

RISE PER DEGREE – A QUICK REFERENCE

Rise (mm) per degree over 1000 mm



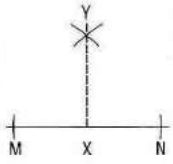
Rise (inches) per degree over 1 foot



A°	B (mm)	A°	B (mm)
1°	17.46	24°	445.23
2°	34.92	25°	466.31
3°	52.41	26°	487.73
4°	69.93	27°	509.53
5°	87.49	28°	531.71
6°	105.10	29°	554.31
7°	122.78	30°	577.35
8°	140.54	31°	600.86
9°	158.38	32°	624.87
10°	176.33	33°	649.41
11°	194.38	34°	674.51
12°	212.56	35°	700.21
13°	230.87	36°	726.54
14°	249.33	37°	753.55
15°	267.95	38°	781.29
16°	286.75	39°	809.78
17°	305.73	40°	839.10
18°	324.92	41°	869.29
19°	344.33	42°	900.40
20°	363.97	43°	932.52
21°	383.86	44°	965.69
22°	404.03	45°	1000.00
23°	424.47		

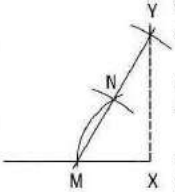
X°	Y (inch)	X°	Y (inch)
1°	0.210	24°	5.343
2°	0.419	25°	5.596
3°	0.629	26°	5.853
4°	0.839	27°	6.114
5°	1.050	28°	6.381
6°	1.261	29°	6.652
7°	1.473	30°	6.928
8°	1.686	31°	7.210
9°	1.901	32°	7.498
10°	2.116	33°	7.793
11°	2.333	34°	8.094
12°	2.551	35°	8.403
13°	2.770	36°	8.718
14°	2.992	37°	9.043
15°	3.215	38°	9.375
16°	3.441	39°	9.717
17°	3.669	40°	10.069
18°	3.899	41°	10.431
19°	4.132	42°	10.805
20°	4.368	43°	11.190
21°	4.606	44°	11.588
22°	4.848	45°	12.000
23°	5.094		

GEOMETRICAL CONSTRUCTION



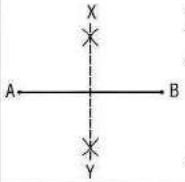
To construct a perpendicular to a line at point X

- Draw arcs on both sides of point **X** having the same radius.
- Draw intersecting arcs from **M** and **N**.
- Connect point of intersection **Y** with point **X**.
- **XY** is the perpendicular of **MN**.



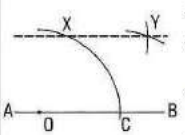
To construct a perpendicular to a straight line at its end point X

- With **X** as centre, draw a sufficiently large arc cutting the base line at one end at **M** extending upwards.
- With **M** as centre, draw an arc to cut the former at **N**.
- With **N** as centre and with the same radius, draw an arc in the same direction.
- Draw a straight line through **M** and **N** to cut the last arc at **Y**.
- The line **XY** is perpendicular to **XM** at point **X**.



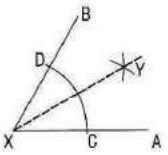
To bisect a line

- With any radius greater than one-half **AB**, draw two arcs from **A** on either side of the line **AB**. Similarly, using the same radius, draw two arcs from **B** intersecting the arcs drawn from point **A**. Draw a line joining points **X** and **Y**.
- The line **XY** is the perpendicular bisector of the line **AB**.



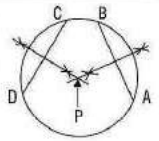
To construct a parallel line to AB through point X

- With **O** as centre, at any point on **AB**, draw a large arc through point **X**, extending downwards to cut the line **AB** at **C**.
- With **X** and **C** as centres and with the same radius, draw arcs to intersect at **Y**.
- A straight line drawn through points **X** and **Y** is parallel to **AB**.



To bisect an angle

- With **X** as centre, draw an arc intersecting **XA** and **XB** at **C** and **D** respectively.
- With **C** and **D** as centres, draw arcs of equal radii intersecting at **Y**.
- **XY** is the required bisector.



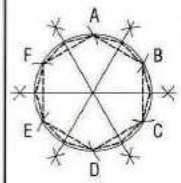
To locate the centre of a circle/arc

- Draw any two chords **AB** and **CD** in the circle.
- The intersecting point **P** of the perpendicular bisectors of the two chords is the centre point required.

GEOMETRICAL CONSTRUCTION

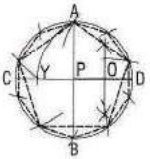
Square/Octagon

- Draw two lines **LN**, **MO** at right angles and a circle whose centre is the point of intersection of these two lines.
- Join the points **LMNO** where the circle cuts the lines, to get the square.
- By drawing the two diagonals which bisect the lines **LM**, **MN**, **NO** and **OL**, the other four corners required to complete the regular octagon can be constructed.



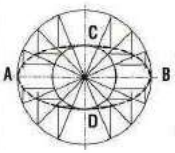
Hexagon/Dodecagon

- Starting at point **A**, mark 6 arcs around the circle equal to the radius of the circle.
- These points are the vertices of the required Hexagon.
- Draw lines bisecting **AB**, **BC** & **CD**, through the centre of the circle. These points together with the vertices of the constructed hexagon, form the vertices of the dodecagon.



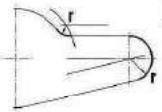
Pentagon/Decagon

- Draw two diameter lines **AB** & **CD** intersecting at right angles at the centre of the circle.
- Bisect radius **PD** at **O**. With **O** as centre and **OA** as radius, mark an arc cutting the horizontal line **CD** at **Y**.
- Length **AY** is the side length of the Pentagon which can be marked off along the circumference.
- To construct a Decagon, mark 5 additional arcs starting from point **B**.



Ellipse by means of two circles

- Draw two concentric circles with diameters **AB** and **CD** representing the major and minor axis of the ellipse to be constructed. Draw additional diameters.
- Now draw vertical lines starting from the points of intersection of these diameters with the circumference of bigger circle.
- Then draw equal number of horizontal lines starting from the points of intersection of the diameters with the circumference of the smaller circle to meet the vertical lines.
- Joining these intersecting points will complete the ellipse.

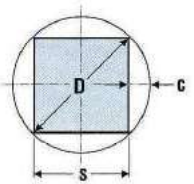


Curvature

- Draw lines parallel to the curvature at a distance = **r**.
- The point of intersection is the centre of the required radii.

USEFUL FORMULAE FOR FINDING DIMENSIONS & AREA OF PLANE FIGURES

Square



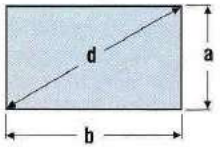
$c = D \times 0.14645$

$D = s \times 1.4142 = 1.414\sqrt{A}$

$s = D \times 0.7071 = \sqrt{A}$

Area A $= s^2 = \frac{1}{2} D^2$

Rectangle



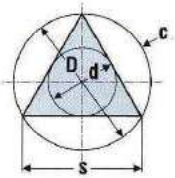
$a = \sqrt{d^2 - b^2} = A \div b$

$b = \sqrt{d^2 - a^2} = A \div a$

$d = \sqrt{a^2 + b^2}$

Area A $= ab = a\sqrt{d^2 - a^2} = b\sqrt{d^2 - b^2}$

Triangle



$c = d \times 0.5 = D \times 0.25$

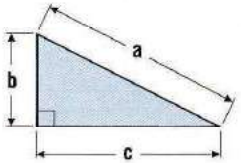
$D = s \times 1.1547 = 2d$

$d = s \times 0.57735$

$s = D \times 0.866$

Right Angle Triangle

(also refer page 54)



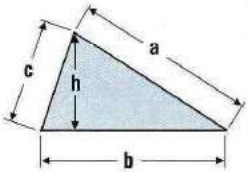
$a = \sqrt{b^2 + c^2}$

$b = \sqrt{a^2 - c^2}$

$c = \sqrt{a^2 - b^2}$

Area A $= \frac{1}{2} b \times c$

Acute Angle Triangle

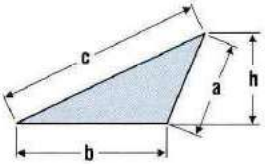


Area A $= \frac{1}{2} b \times h$

Also **Area A** $= \sqrt{S(S-a)(S-b)(S-c)}$

where $S = \frac{1}{2}(a + b + c)$

Obtuse Angle Triangle



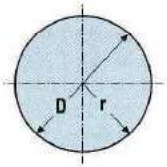
Area A $= \frac{1}{2} b \times h$

Also **Area A** $= \sqrt{S(S-a)(S-b)(S-c)}$

where $S = \frac{1}{2}(a + b + c)$

USEFUL FORMULAE FOR FINDING DIMENSIONS & AREA OF PLANE FIGURES

Circle



Circumference C $= 2\pi r = 6.2832r = 3.1416d$

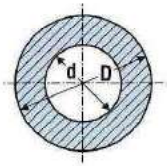
$D = C \div 3.1416 = A \div 0.7854 = 1.128\sqrt{A}$

$r = C \div 6.2832 = A \div 3.1416 = 0.564\sqrt{A}$

Area A $= \pi r^2 = 3.1416r^2$

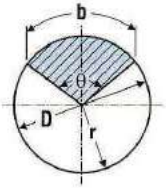
Also **Area A** $= \frac{\pi D^2}{4} = 0.7854D^2$

Hollow Circle



Area A $= 0.785(D^2 - d^2)$

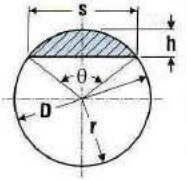
Sector of Circle



Arc length $b = \frac{\pi \times D \times \theta}{360}$

Area A $= \frac{b \times r}{2}$

Segment of a Circle

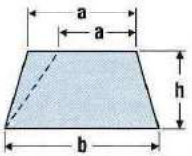


Area A $= \frac{\pi \times r^2 \times \theta}{360} - \frac{s(r-h)}{2}$

where $s = 2r \times \sin\left(\frac{\theta}{2}\right)$

and $h = r\left(1 - \cos\left(\frac{\theta}{2}\right)\right)$

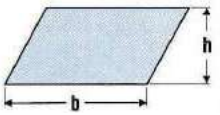
Trapezium / Trapezoid



Area A $= \frac{a+b}{2} \times h$

where $a = \frac{2A}{h} - b$, $b = \frac{2A}{h} - a$, $h = \frac{2A}{a+b}$

Parallelogram



Area A $= b \times h$

where $b = \frac{A}{h}$, $h = \frac{A}{b}$

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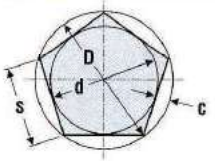
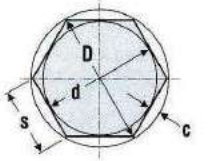
USEFUL FORMULAE FOR FINDING DIMENSIONS & AREA OF PLANE FIGURES

Pentagon



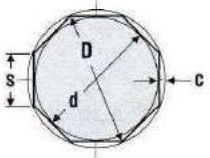
c = D x 0.0955
D = s x 1.7013 = d x 1.2361
d = s x 1.3764 = D x 0.809
s = D x 0.5878
Area A = s^2 x 1.7205

Hexagon



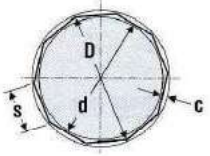
c = D x 0.067
D = s x 2 = d x 1.1547
d = s x 1.7321 = D x 0.866
s = D x 0.5
Area A = s^2 x 2.5981

Octagon



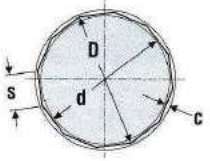
c = D x 0.038
D = s x 2.6131 = d x 1.0824
d = s x 2.4142 = D x 0.9239
s = D x 0.3827
Area A = s^2 x 4.8284

Decagon (10 sides)



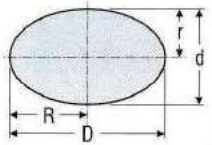
c = D x 0.0245
D = s x 3.2360 = d x 1.0515
d = s x 3.0776 = D x 0.9511
s = D x 0.3090
Area A = s^2 x 7.6942

Dodecagon (12 sides)



c = D x 0.0170
D = s x 3.8637 = d x 1.0353
d = s x 3.7320 = D x 0.9659
s = D x 0.2588
Area A = s^2 x 11.1961

Ellipse



Area A = $\frac{\pi}{4}$ x D x d = 0.785 x D x d

Circumference C can be calculated and depends on the ratio d : D (Refer table)

d : D	C = D times	d : D	C = D times
0.2	2.1010	0.6	2.5527
0.3	2.1930	0.7	2.6912
0.4	2.3013	0.8	2.9361
0.5	2.4221	0.9	2.9866

Example : To calculate C when d = 100 mm, D = 200 mm
ratio d : D = 100 ÷ 200 = 0.5
∴ C = D x ratio
∴ C = D x 2.4221
= 200 x 2.4221 = 484.42 mm

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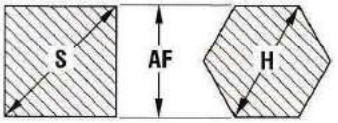
DISTANCE ACROSS CORNERS OF SQUARES & HEXAGONS

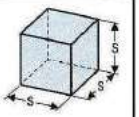


S = 1.414214 x AF
H = 1.154701 x AF

METRIC						INCH		
AF (mm)	S (mm)	H (mm)	AF (mm)	S (mm)	H (mm)	AF (inch)	S (inch)	H (inch)
1	1.4142	1.1547	41	57.9828	47.3427	1/32"	0.0442	0.0361
2	2.8284	2.3094	42	59.3970	48.4974	1/16"	0.0884	0.0722
3	4.2426	3.4641	43	60.8112	49.6521	3/32"	0.1326	0.1083
4	5.6569	4.6188	44	62.2254	50.8068	1/8"	0.1768	0.1443
5	7.0711	5.7735	45	63.6396	51.9615	5/32"	0.2210	0.1804
6	8.4853	6.9282	46	65.0538	53.1162	3/16"	0.2652	0.2165
7	9.8995	8.0829	47	66.4681	54.2709	7/32"	0.3094	0.2526
8	11.3137	9.2376	48	67.8823	55.4256	1/4"	0.3536	0.2887
9	12.7279	10.3923	49	69.2965	56.5803	9/32"	0.3977	0.3248
10	14.1421	11.5470	50	70.7107	57.7351	5/16"	0.4419	0.3608
11	15.5564	12.7017	51	72.1249	58.8898	11/32"	0.4861	0.3969
12	16.9706	13.8564	52	73.5391	60.0445	3/8"	0.5303	0.4330
13	18.3848	15.0111	53	74.9533	61.1992	13/32"	0.5745	0.4691
14	19.7990	16.1658	54	76.3676	62.3539	7/16"	0.6187	0.5052
15	21.2132	17.3205	55	77.7818	63.5086	15/32"	0.6629	0.5413
16	22.6274	18.4752	56	79.1960	64.6633	1/2"	0.7071	0.5774
17	24.0416	19.6299	57	80.6102	65.8180	17/32"	0.7513	0.6134
18	25.4559	20.7846	58	82.0244	66.9727	9/16"	0.7955	0.6495
19	26.8701	21.9393	59	83.4386	68.1274	19/32"	0.8397	0.6856
20	28.2843	23.0940	60	84.8528	69.2821	5/8"	0.8839	0.7217
21	29.6985	24.2487	61	86.2671	70.4368	21/32"	0.9281	0.7578
22	31.1127	25.4034	62	87.6813	71.5915	11/16"	0.9723	0.7939
23	32.5269	26.5581	63	89.0955	72.7462	23/32"	1.0165	0.8299
24	33.9411	27.7128	64	90.5097	73.9009	3/4"	1.0607	0.8660
25	35.3554	28.8675	65	91.9239	75.0556	25/32"	1.1049	0.9021
26	36.7696	30.0222	66	93.3381	76.2103	13/16"	1.1490	0.9382
27	38.1838	31.1769	67	94.7523	77.3650	27/32"	1.1932	0.9743
28	39.5980	32.3316	68	96.1666	78.5197	7/8"	1.2374	1.0104
29	41.0122	33.4863	69	97.5808	79.6744	29/32"	1.2816	1.0464
30	42.4264	34.6410	70	98.9950	80.8291	15/16"	1.3258	1.0825
31	43.8406	35.7957	71	100.4092	81.9838	31/32"	1.3700	1.1186
32	45.2548	36.9504	72	101.8234	83.1385	1"	1.4142	1.1547
33	46.6691	38.1051	73	103.2376	84.2932	1 1/8"	1.5910	1.2990
34	48.0833	39.2598	74	104.6518	85.4479	1 1/4"	1.7678	1.4434
35	49.4975	40.4145	75	106.0661	86.6026	1 3/8"	1.9445	1.5877
36	50.9117	41.5692	76	107.4803	87.7573	1 1/2"	2.1213	1.7321
37	52.3259	42.7239	77	108.8945	88.9120	1 5/8"	2.2981	1.8764
38	53.7401	43.8786	78	110.3087	90.0667	1 3/4"	2.4749	2.0207
39	55.1543	45.0333	79	111.7229	91.2214	1 7/8"	2.6517	2.1651
40	56.5686	46.1880	80	113.1371	92.3761	2"	2.8284	2.3094

USEFUL FORMULAE FOR FINDING AREA & VOLUME OF SOLID FIGURES

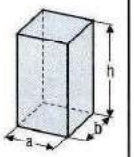
Cube



Surface area = $6 \times s \times s = 6s^2$

Volume = $s \times s \times s = s^3$

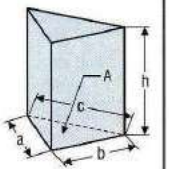
Prism



Surface area = $2(a \times b) + 2(a \times h) + 2(b \times h)$

Volume = $a \times b \times h$

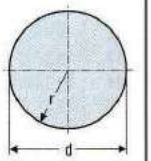
Prism



Surf. Area = 2 x area base A + $(a \times h) + (b \times h) + (c \times h)$

Volume = area base A x h

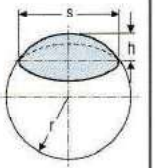
Sphere



Surface area = $\pi \times d^2 = 3.1416d^2$

Volume = $\frac{\pi \times d^3}{6} = 0.5236d^3$

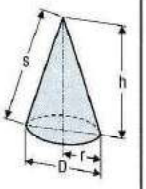
Spherical Segment



Surface area of segment = $2\pi rh$

Volume = $\pi \times h^2\left(r - \frac{h}{3}\right)$ *or* $= \pi \times h\left(\frac{s^2}{8} + \frac{h^2}{6}\right)$

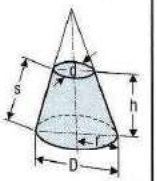
Cone



Surface area = $\frac{\pi}{4} \times D^2(D + 2s)$

Volume = $\frac{\pi}{4} \times D^2 \times \frac{h}{3}$

Frustum of a Cone

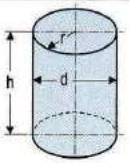


Surface area = $.7854D^2 + .7854d^2 + \pi \times \frac{D + d}{2} \times s$

Volume = $\frac{\pi}{12} \times h\,(D^2 + D \times d + d^2)$

USEFUL FORMULAE FOR FINDING AREA & VOLUME OF SOLID FIGURES

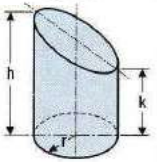
Cylinder



Surface area = $\pi \times d \times h + 2\pi r^2$

Volume = $\frac{\pi}{4} \times d^2 \times h$ *or* $= \pi r^2 h$

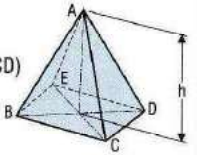
Frustum of a Cylinder



Area of cylindrical surface = $\pi \times r \times (h + k)$

Volume = $\frac{\pi}{2} \times r^2 \times (h + k)$

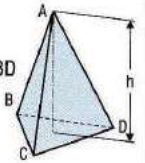
Pyramid (Square/Rectangular base)



Surface area = BC x CD + 2 (area $\triangle$ABC) + 2 (area $\triangle$ACD)

Volume = $\frac{BC \times CD \times h}{3}$

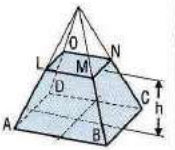
Pyramid (Triangular base)



Surf. area = area $\triangle$BCD + area $\triangle$ABC + area $\triangle$ACD + area $\triangle$ABD

Volume = $\frac{\text{area } \triangle BCD \times h}{3}$

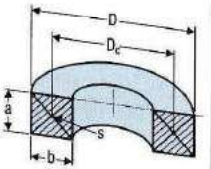
Frustum of a Pyramid (Square base)



Surface area = area ABCD + area LMNO + 4(area ABML)

Volume = $\frac{h}{3}\,(LM)^2 + LM \times AB + (AB)^2$

Solids of Revolution



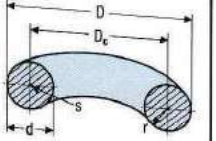
Surface area = $\pi^2 \times D \times D_c$

Volume = $a \times b \times \pi \times D_c$

NOTE : s = centre of gravity of cross-section

D_c = diameter of circle of centre of gravity

Ring of Circular Cross-Section



Surface area = $\pi^2 \times d \times D_c$

Volume = $\frac{\pi}{4} \times d^2 \times \pi \times D_c$

NOTE : s = centre of gravity of cross-section

D_c = diameter of circle of centre of gravity

USEFUL TAPERS & ANGLES USED IN THE WORKSHOP

Cone of	Taper per inch on diameter	INCLUDED ANGLE		
		Degrees	Minutes	Seconds
1 in 96	0.010417		35	47
1 in 60	0.016666		57	17
1 in 50	0.020000	1	8	46
1 in 48	0.020833	1	11	38
1 in 40	0.025000	1	25	56
1 in 30	0.033333	1	54	36
1 in 24	0.041666	2	23	12
1 in 20	0.050000	2	51	52
1 in 19	0.052632	3	0	54
1 in 18	0.055555	3	10	58
1 in 17	0.058824	3	22	9
1 in 16	0.062500	3	34	48
1 in 15	0.066666	3	49	6
1 in 14	0.071429	4	5	26
1 in 13	0.076923	4	24	18
1 in 12	0.083333	4	46	19
1 in 11	0.090909	5	12	18
1 in 10	0.100000	5	43	31
1 in 9 1/2	0.105263	6	1	32
1 in 9	0.111111	6	21	34
1 in 8 1/2	0.117647	6	43	58
1 in 8	0.125000	7	9	10
1 in 7 1/2	0.133333	7	37	41
1 in 7	0.142857	8	10	16
1 in 6 1/2	0.153846	8	47	51
1 in 6	0.166666	9	31	37
1 in 5 1/2	0.181818	10	23	20
1 in 5	0.200000	11	25	16
1 in 4	0.250000	14	15	0
1 in 3	0.333333	18	55	28
1 in 2	0.500000	28	4	20

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USEFUL TAPERS & ANGLES USED IN THE WORKSHOP

Taper per foot on diameter	Taper per inch on diameter	INCLUDED ANGLE		
		Degrees	Minutes	Seconds
1/16"	0.005208		17	53
1/8"	0.010416		35	47
3/16"	0.015625		53	44
1/4"	0.020833	1	11	38
5/16"	0.026041	1	29	31
3/8"	0.031250	1	47	25
7/16"	0.036446	2	5	18
1/2"	0.041667	2	23	12
9/16"	0.046875	2	41	7
5/8"	0.052084	2	59	3
11/16"	0.057292	3	16	56
3/4"	0.062500	3	34	48
13/16"	0.067708	3	52	42
7/8"	0.072917	4	10	32
15/16"	0.078125	4	28	26
1"	0.083330	4	46	19
1 1/8"	0.093750	5	22	2
1 1/4"	0.104166	5	57	45
1 3/8"	0.114583	6	33	29
1 1/2"	0.125000	7	9	10
1 5/8"	0.135417	7	44	49
1 3/4"	0.145833	8	20	28
2"	0.166666	9	31	37
2 1/2"	0.208333	11	53	38
3"	0.250000	14	15	0
3 1/2"	0.291666	16	35	41
4"	0.333333	18	55	28
4 1/2"	0.375000	21	14	22
5"	0.416666	23	32	12
5 1/2"	0.458333	25	48	53
6"	0.500000	28	4	20

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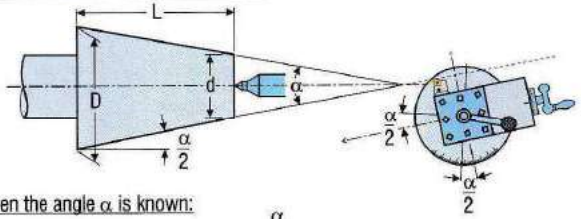
TAPER TURNING ON A STANDARD LATHE

1. Swiveling the Compound Slide



- When the angle α is known:
  The compound slide is rotated by $\frac{\alpha}{2}$ (½ the taper angle).
- When the dimensions are given:
  The angle can be calculated using the formula: $\text{Tan}\ \frac{\alpha}{2} = \frac{D-d}{2L}$

Example: When D = 80 mm, d = 56.3 mm, L = 50 mm,

$\text{Tan}\frac{\alpha}{2} = \frac{80.0-56.3}{100} \quad \therefore \text{Tan}\frac{\alpha}{2} = \frac{23.7}{100} = .237$

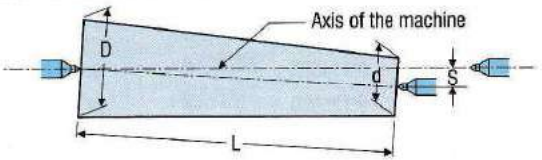
The result can now be looked up in the Table of Natural Tangents on page 158.

Therefore $\frac{\alpha}{2} = 13°20'$

2. Offsetting the Tail Stock

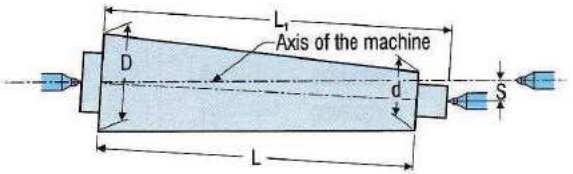
- When the length of taper = length of workpiece: Offset $S = \frac{D-d}{2}$

The Tail Stock will have to be offset forward at a distance = S, noting that the tool must travel parallel to the axis of the machine.



- When the length of taper < length of workpiece: Offset $S = \frac{D-d}{2 \times L} \times L_1$

The Tail Stock will have to be offset forward at a distance = S, noting that the tool must travel parallel to the axis of the machine.



NOTE : Taper turning by offsetting the tail stock has its limitations and is applicable to tapers (α) less than 7°.

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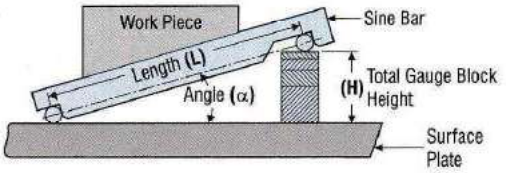
SINE BAR & SINE PLATE SETTING

The Sine Bar is used for accurately setting up work for machining or for inspection purposes. It consists of a hardened Steel Bar with two pins mounted at an accurate pre-determined distance. A Sine Bar can be of any length. However, 100 mm, 125 mm & 200 mm are common Metric sizes and 5" and 10" are common Inch sizes.



Gauge blocks are used for establishing the setting height **(H)** of the Sine Bar.
The setting height **(H)** can be determined by multiplying the Sine of the given angle by the length of the Sine Bar. (Refer pages 156 and 157 - Table of Natural Sines).

Height (H) = Sine α x L where, **H** = Setting Height, **L** = Length of Sine Bar

Sine $\alpha = \frac{H}{L}$

Examples using a 200 mm Sine Bar

To find H when given angle = 15°.

H = Sine 15° x L = .25882 x 200

∴ **H = 51.764 mm** (total gauge block height)

To find ∠ when given height (H) = 100 mm

$\text{Sine}\ \alpha = \frac{H}{L} = \frac{100}{200} = .5000$

∴ **α = 30°**

Examples using a 5 inch Sine Bar

To find H when given angle = 15°.

H = Sine 15° x L = .25882 x 5

∴ **H = 1.2941"** (total gauge block height)

To find ∠ when given height (H) = 2.50 in.

$\text{Sine}\ \alpha = \frac{H}{L} = \frac{2.50}{5} = .5000$

∴ **α = 30°**

Rules for working out Inch Tapers (Also refer pages 64 & 65)

To Find	Given	Rule
Taper per inch	Taper per foot	Divide the taper per foot by 12.
Taper per foot	Taper per inch	Multiply the taper per inch by 12.
Taper per foot	End diameters and length of tapers in inches	Subtract small dia. from large dia., then divide by length of taper, & multiply quotient by 12.
Diameter at small end in inches	Large diameter, length of taper in inches, and taper per foot	Divide taper per foot by 12, multiply by length of taper, & subtract from large dia.
Diameter at large end in inches	Small diameter, length of taper in inches, and taper per foot	Divide taper per foot by 12, multiply by length of taper, & add result to small dia.
Distance between 2 given diameters in inches	Taper per foot and two diameters in inches	Subtract small dia. from large dia., then divide remainder by taper per foot & multiply quotient by 12.

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DIVIDING HEAD - INDEXING CHART
WORM GEAR RATIO 40:1

No. of Divisions	Hole Circle	Complete Turns	Fraction of a Turn
2	Any	20	--
3	39	13	13/39
3	27	13	9/27
4	Any	10	--
5	Any	8	--
6	39	6	26/39
6	27	6	18/27
7	49	5	35/49
7	21	5	15/21
8	Any	5	--
9	27	4	12/27
9	18	4	8/18
10	Any	4	--
11	33	3	21/33
12	39	3	13/39
12	27	3	9/27
13	39	3	3/39
14	49	2	42/49
14	21	2	18/21
15	39	2	26/39
15	27	2	18/27
16	20	2	10/20
17	17	2	6/17
18	27	2	6/27
18	18	2	4/18
19	19	2	2/19
20	Any	2	--
21	21	1	19/21
22	33	1	27/33
23	23	1	17/23
24	39	1	26/39
24	27	1	18/27
25	20	1	12/20
26	39	1	21/39
27	27	1	13/27
28	49	1	21/49
28	21	1	9/21
29	29	1	11/29
30	39	1	13/39
30	27	1	9/27
31	31	1	9/31
32	20	1	5/20
33	33	1	7/33
34	17	1	3/17
35	49	1	7/49
35	21	1	3/21
36	27	1	3/27
37	37	1	3/37
38	19	1	1/19
39	39	1	1/39
40	Any	1	--

No. of Divisions	Hole Circle	Fraction of a Turn
41	41	40/41
42	21	20/21
43	43	40/43
44	33	30/33
45	27	24/27
46	23	20/23
47	47	40/47
48	18	15/18
49	49	40/49
50	20	16/20
52	39	30/39
54	27	20/27
55	33	24/33
56	49	35/49
58	29	20/29
60	39	26/39
60	27	18/27
62	31	20/31
64	16	10/16
65	39	24/39
66	33	20/33
68	17	10/17
70	49	28/49
72	27	15/27
74	37	20/37
75	15	8/15
76	19	10/19
78	39	20/39
80	20	10/20
82	41	20/41
84	21	10/21
85	17	8/17
86	43	20/43
88	33	15/33
90	27	12/27
92	23	10/23
94	47	20/47
95	19	8/19
98	49	20/49
100	20	8/20
104	39	15/39
105	21	8/21
115	23	8/23
116	29	10/29
120	39	13/39
120	27	9/27

No. of Divisions	Hole Circle	Fraction of a Turn
124	31	10/31
128	16	5/16
130	39	12/39
132	33	10/33
135	27	8/27
136	17	5/17
140	49	14/49
144	18	5/18
145	29	8/29
148	37	10/37
150	15	4/15
152	19	5/19
155	31	8/31
156	39	10/39
160	20	5/20
164	41	10/41
165	33	8/33
168	21	5/21
170	17	4/17
172	43	10/43
180	27	6/27
185	37	8/37
188	47	10/47
190	19	4/19
195	39	8/39
196	49	10/49
200	20	4/20
205	41	8/41
210	21	4/21
215	43	8/43
216	27	5/27
220	33	6/33
230	23	4/23
232	29	5/29
235	47	8/47
240	18	3/18
245	49	8/49
248	31	5/31
260	39	6/39
264	33	5/33
270	27	4/27
280	49	7/49
290	29	4/29
296	37	5/37
300	15	2/15
360	18	2/18

Index Plate	No of Holes
A	15, 16, 17, 18, 19, 20
B	21, 23, 27, 29, 31, 33
C	37, 39, 41, 43, 47, 49

OR

Index Plate	No of Holes
No. 1	15, 18, 20, 23, 27, 31, 37, 41, 47
No. 2	16, 17, 19, 21, 29, 33, 39, 43, 49

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ROTARY TABLE - INDEXING CHART
WORM GEAR RATIO 90:1

No. of Divisions	Hole Circle	Complete Turns	Fraction of a Turn
2	Any	45	--
3	Any	30	--
4	26	22	13/26
4	28	22	14/28
5	Any	18	--
6	Any	15	--
7	28	12	24/28
7	77	12	66/77
8	28	11	7/28
8	44	11	11/44
9	Any	10	--
10	Any	9	--
11	44	8	8/44
11	77	8	14/77
12	26	7	13/26
12	28	7	14/28
13	26	6	24/26
13	91	6	84/91
14	28	6	12/28
14	77	6	33/77
15	Any	6	--
16	32	5	20/32
17	34	5	10/34
18	Any	5	--
19	38	4	28/38
20	26	4	13/26
20	28	4	14/28
21	28	4	8/28
21	77	4	22/77
22	44	4	4/44
22	77	4	7/77
23	46	3	42/46
23	69	3	63/69
24	28	3	21/28
24	44	3	33/44
25	30	3	18/30
26	26	3	12/26
26	91	3	42/91
27	30	3	10/30
27	63	3	21/63
28	28	3	6/28
29	87	3	9/87
30	Any	3	--
31	93	2	84/93

No. of Divisions	Hole Circle	Complete Turns	Fraction of a Turn
32	32	2	26/32
33	99	2	72/99
34	34	2	22/34
35	28	2	16/28
35	63	2	36/63
36	26	2	13/26
36	28	2	14/28
37	37	2	16/37
38	38	2	14/38
39	26	2	8/26
39	91	2	28/91
40	28	2	7/28
40	44	2	11/44
41	41	2	8/41
42	28	2	4/28
42	63	2	9/63
43	43	2	4/43
44	44	2	2/44
45	Any	2	--
46	46	1	44/46
46	69	1	66/69
47	47	1	43/47
48	32	1	28/32
49	49	1	41/49
50	30	1	24/30
51	34	1	26/34
52	26	1	19/26
53	53	1	37/53
54	30	1	20/30
54	63	1	42/63
55	44	1	28/44
55	77	1	49/77
56	28	1	17/28
57	38	1	22/38
58	87	1	48/87
59	59	1	31/59
60	34	1	17/34
60	32	1	16/32
61	61	1	29/61
62	93	1	42/93
63	49	1	21/49
63	77	1	33/77
64	32	1	13/32
65	26	1	10/26

No. of Divisions	Hole Circle	Complete Turns	Fraction of a Turn
65	91	1	35/91
66	44	1	16/44
66	99	1	36/99
67	67	1	23/67
68	34	1	11/34
69	46	1	14/46
69	69	1	21/69
70	28	1	8/28
70	63	1	18/63
71	71	1	19/71
72	32	1	8/32
72	44	1	11/44
73	73	1	17/73
74	37	1	8/37
75	30	1	6/30
76	38	1	7/38
77	77	1	13/77
78	39	1	6/39
78	91	1	14/91
79	79	1	11/79
80	32	1	4/32
81	63	1	7/63
81	81	1	9/81
82	41	1	4/41
83	83	1	7/83
84	28	1	2/28
85	34	1	2/34
86	43	1	2/43
87	87	1	3/87
88	44	1	1/44
89	89	1	1/89
90	Any	1	--
91	91	--	90/91
92	46	--	45/46
93	93	--	90/93
94	47	--	45/47
95	38	--	36/38
96	32	--	30/32
97	97	--	90/97
98	49	--	45/49
99	44	--	40/44
99	99	--	90/99
100	30	--	27/30

Index Plate	No of Holes
A	26, 28, 30, 32, 34, 37, 38, 39, 41, 43, 44, 46, 47, 49, 51, 53, 57, 59
B	61, 63, 67, 69, 71, 73, 77, 79, 81, 83, 87, 89, 91, 93, 97, 99

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USEFUL TOLERANCES

Tolerances in mm

Tolerance		Nominal Diameter (mm) from 1 to 3	over 3 to 6	over 6 to 10	over 10 to 18	over 18 to 30	over 30 to 50	over 50 to 80	over 80 to 120
SHAFTS	e^8	-.014 -.028	-.020 -.038	-.025 -.047	-.032 -.059	-.040 -.073	-.050 -.089	-.060 -.106	-.072 -.126
	e^9	-.014 -.039	-.020 -.050	-.025 -.061	-.032 -.075	-.040 -.092	-.050 -.112	-.060 -.134	-.072 -.159
	f^6	-.006 -.012	-.010 -.018	-.013 -.022	-.016 -.027	-.020 -.033	-.025 -.041	-.030 -.049	-.036 -.058
	f^7	-.006 -.016	-.010 -.022	-.013 -.028	-.016 -.034	-.020 -.041	-.025 -.050	-.030 -.060	-.036 -.071
	g^6	-.002 -.008	-.004 -.012	-.005 -.014	-.006 -.017	-.007 -.020	-.009 -.025	-.010 -.029	-.012 -.034
	h^6	.000 -.006	.000 -.008	.000 -.009	.000 -.011	.000 -.013	.000 -.016	.000 -.019	.000 -.022
	h^7	.000 -.010	.000 -.012	.000 -.015	.000 -.018	.000 -.021	.000 -.025	.000 -.030	.000 -.035
	h^8	.000 -.014	.000 -.018	.000 -.022	.000 -.027	.000 -.033	.000 -.039	.000 -.046	.000 -.054
	h^9	.000 -.025	.000 -.030	.000 -.036	.000 -.043	.000 -.052	.000 -.062	.000 -.074	.000 -.087
	h^{11}	.000 -.060	.000 -.075	.000 -.090	.000 -.110	.000 -.130	.000 -.160	.000 -.190	.000 -.220
	h^{12}	.000 -.100	.000 -.120	.000 -.150	.000 -.180	.000 -.210	.000 -.250	.000 -.300	.000 -.350
	k^6	+.006 .000	+.009 +.001	+.010 +.001	+.012 +.001	+.015 +.002	+.018 +.002	+.021 +.002	+.025 +.003
	n^6	+.010 +.004	+.016 +.008	+.019 +.010	+.023 +.012	+.028 +.015	+.033 +.017	+.039 +.020	+.045 +.023
	p^6	+.012 +.006	+.020 +.012	+.024 +.015	+.029 +.018	+.035 +.022	+.042 +.026	+.051 +.032	+.059 +.037
HOLES	F^8	+.020 +.006	+.028 +.010	+.035 +.013	+.043 +.016	+.053 +.020	+.064 +.025	+.076 +.030	+.090 +.036
	G^7	+.012 +.002	+.016 +.004	+.020 +.005	+.024 +.006	+.028 +.007	+.034 +.009	+.040 +.010	+.047 +.012
	H^7	+.010 .000	+.012 .000	+.015 .000	+.018 .000	+.021 .000	+.025 .000	+.030 .000	+.035 .000
	H^8	+.014 .000	+.018 .000	+.022 .000	+.027 .000	+.033 .000	+.039 .000	+.046 .000	+.054 .000
	H^9	+.025 .000	+.030 .000	+.036 .000	+.043 .000	+.052 .000	+.062 .000	+.074 .000	+.087 .000
	H^{12}	+.100 .000	+.120 .000	+.150 .000	+.180 .000	+.210 .000	+.250 .000	+.300 .000	+.350 .000

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METRIC & INCH DESIGNATIONS FOR ANSI PREFERRED LIMITS & FITS

(ANSI B4.1-1967, R1979) & (ANSI B4.2-1978, R1984)

The following chart covers a selection of Preferred Fits (Hole Basis) for Holes & Shafts which will meet the needs of a large proportion of the requirements for Standard Engineering Components.

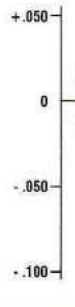
METRIC	INCH	Description / Application
Hole & Shaft Designation Symbols		**CLEARANCE FITS**
H^{11} / c^{11}	H^{10} / c^9 (Rc_8)	**LOOSE RUNNING FIT** - Wide commercial tolerances, used where accuracy is not essential.
H^9 / d^9	H^9 / d^8 (Rc_7)	**FREE RUNNING FIT** - High running speeds, large temperature variations, heavy pressures and where accuracy is not essential.
H^8 / f^7	H^8 / f^7 (Rc_4)	**CLOSE RUNNING FIT** - Accurate location at moderate speeds on accurate machines.
H^7 / g^6	H^6 / g^5 (Rc_2)	**SLIDING FIT** - Accurate location where components are intended to move and turn freely but not run freely.
H^7 / h^6	H^7 / h^6 (Lc_2)	**LOCATIONAL CLEARANCE FIT** - Snug fit for locating stationary components which need to be freely assembled and disassembled.
		TRANSITION FITS
H^7 / k^6	H^7 / k^6 (Lt_3)	**LOCATIONAL TRANSITION FIT** (Tap Fit) - Accurate location where assembly requires gentle persuasion.
H^7 / n^6	H^7 / n^6 (Lt_5)	**LOCATIONAL TRANSITION FIT** - More accurate location where assembly permits greater interference.
		INTERFERENCE FITS
H^7 / p^6	H^7 / p^6 (Ln_2)	**LOCATIONAL INTERFERENCE** - Prime accuracy of location where assembly requires alignment and rigidity.
H^7 / s^6	H^7 / s^6 (FN_2)	**MEDIUM DRIVE FIT** (Press Fit) - For assembly of steel parts and shrink fits on light sections.
H^7 / u^6	H^7 / u^6 (Fn_4)	**FORCE FIT** (Press Fit) - For assembly of components where high pressures and stresses are permitted.

NOTE : See pages 74 & 75 for METRIC and pages 72 & 73 for INCH tolerances.

PREFERRED LIMITS & FITS

The following chart covers a simple selection of Preferred Fits (Hole Basis) for Holes & Shafts which will meet the needs of a large proportion of the requirements for Standard Engineering Components. **(Refer page 71 for Fit Designations).**

To scale for diameter range 18 mm to 30 mm



Type of Fit

CLEARANCE

Free Running	Close Running	Sliding	Locational Clearance

Tolerances in mm

Nominal Dia. (mm) Above	Upto & incl.	H9	e9	H8	f7	H7	g6	H7	h6
0	3	+.025 .000	-.014 -.039	+.014 .000	-.006 -.016	+.010 .000	-.002 -.008	+.010 .000	-.006 .000
3	6	+.030 .000	-.020 -.050	+.018 .000	-.010 -.022	+.012 .000	-.004 -.012	+.012 .000	-.008 .000
6	10	+.036 .000	-.025 -.061	+.022 .000	-.013 -.028	+.015 .000	-.005 -.014	+.015 .000	-.009 .000
10	18	+.043 .000	-.032 -.075	+.027 .000	-.016 -.034	+.018 .000	-.006 -.017	+.018 .000	-.011 .000
18	30	+.052 .000	-.040 -.092	+.033 .000	-.020 -.041	+.021 .000	-.007 -.020	+.021 .000	-.013 .000
30	50	+.062 .000	-.050 -.112	+.039 .000	-.025 -.050	+.025 .000	-.009 -.025	+.025 .000	-.016 .000
50	80	+.074 .000	-.060 -.134	+.046 .000	-.030 -.060	+.030 .000	-.010 -.029	+.030 .000	-.019 .000
80	120	+.087 .000	-.072 -.159	+.054 .000	-.036 -.071	+.035 .000	-.012 -.034	+.035 .000	-.022 .000
120	180	+.100 .000	-.084 -.185	+.063 .000	-.043 -.083	+.040 .000	-.014 -.039	+.040 .000	-.025 .000
180	250	+.115 .000	-.100 -.215	+.072 .000	-.050 -.096	+.046 .000	-.015 -.044	+.046 .000	-.029 .000
250	315	+.130 .000	-.110 -.240	+.081 .000	-.056 -.108	+.052 .000	-.017 -.049	+.052 .000	-.032 .000
315	400	+.140 .000	-.125 -.265	+.089 .000	-.062 -.119	+.057 .000	-.018 -.054	+.057 .000	-.036 .000
400	500	+.155 .000	-.135 -.290	+.097 .000	-.068 -.131	+.063 .000	-.020 -.060	+.063 .000	-.040 .000

PREFERRED LIMITS & FITS

The following chart covers a simple selection of Preferred Fits (Hole Basis) for Holes & Shafts which will meet the needs of a large proportion of the requirements for Standard Engineering Components. **(Refer page 71 for Fit Designations).**

To scale for diameter range 30 mm to 50 mm

Type of Fit

TRANSITION		INTERFERENCE	
Locational Transition	Locational Transition	Locational Interference	Medium Drive

Tolerances in mm

Nominal Size (mm) Above	Upto & incl.	H7	k6	H7	n6	H7	p6	H7	s6
0	3	+.010 .000	+.006 .000	+.010 .000	+.010 +.004	+.010 .000	+.012 +.006	+.010 .000	+.020 +.014
3	6	+.012 .000	+.009 +.001	+.012 .000	+.016 +.008	+.012 .000	+.020 +.012	+.012 .000	+.027 +.019
6	10	+.015 .000	+.010 +.001	+.015 .000	+.019 +.010	+.015 .000	+.024 +.015	+.015 .000	+.032 +.023
10	18	+.018 .000	+.012 +.001	+.018 .000	+.023 +.012	+.018 .000	+.029 +.018	+.018 .000	+.039 +.028
18	30	+.021 .000	+.015 +.002	+.021 .000	+.028 +.015	+.021 .000	+.035 +.022	+.021 .000	+.048 +.035
30	50	+.025 .000	+.018 +.002	+.025 .000	+.033 +.017	+.025 .000	+.042 +.026	+.025 .000	+.059 +.043
50	65	+.030 .000	+.021 +.002	+.030 .000	+.039 +.020	+.030 .000	+.051 +.032	+.030 .000	+.072 +.053
65	80							+.030 .000	+.078 +.059
80	100	+.035 .000	+.025 +.003	+.035 .000	+.045 +.023	+.035 .000	+.059 +.037	+.035 .000	+.093 +.071
100	120							+.035 .000	+.101 +.079
120	140	+.040 .000	+.028 +.003	+.040 .000	+.052 +.027	+.040 .000	+.068 +.043	+.040 .000	+.117 +.092
140	160							+.040 .000	+.125 +.100
160	180							+.040 .000	+.133 +.108
180	200	+.046 .000	+.033 +.004	+.046 .000	+.060 +.031	+.046 .000	+.079 +.050	+.046 .000	+.151 +.122
200	225							+.046 .000	+.159 +.130
225	250							+.046 .000	+.169 +.140
250	280	+.052 .000	+.036 +.004	+.052 .000	+.066 +.034	+.052 .000	+.088 +.056	+.052 .000	+.190 +.158
280	315							+.052 .000	+.202 +.170
315	355	+.057 .000	+.040 +.004	+.057 .000	+.073 +.037	+.057 .000	+.098 +.062	+.057 .000	+.226 +.190
355	400							+.057 .000	+.244 +.208
400	450	+.063 .000	+.045 +.005	+.063 .000	+.080 +.040	+.063 .000	+.108 +.068	+.063 .000	+.272 +.232
450	500							+.063 .000	+.292 +.252

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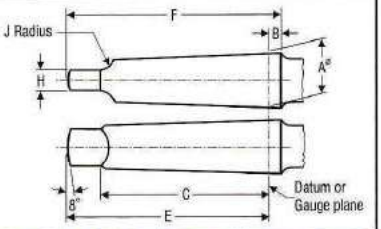
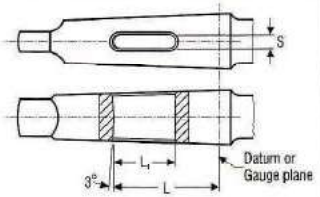
DIMENSIONS OF MORSE TAPER SHANKS/SOCKETS (For Identification Purposes)

Morse Taper Shank



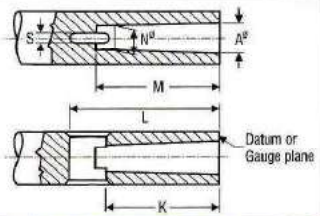
Morse Taper No.	A (mm)	B (mm)	C (mm)	E (mm)	F (mm)	H (mm)	J (mm)	Taper per mm. on dia.	Included Angle Deg.	Min.	Sec.
0	9.045	3.0	51.0	56.5	59.5	3.9	4	0.05205	2	58	54
1	12.065	3.5	53.5	62.0	65.5	5.2	5	0.04988	2	51	27
2	17.780	5.0	65.0	75.0	80.0	6.3	6	0.04995	2	51	41
3	23.825	5.0	81.0	94.0	99.0	7.9	7	0.05020	2	52	31
4	31.267	6.5	101.5	117.5	124.0	11.9	8	0.05194	2	58	31
5	44.399	6.5	130.5	149.5	156.0	15.9	10	0.05263	3	0	52
6	63.348	8.0	183.0	210.0	218.0	19.0	13	0.05214	2	59	12
7	83.058	10.0	251.0	286.0	296.0	28.6	19	0.05200	2	56	44

Morse Taper Shank with Wedge Drive Slot



Morse Taper No.	L (mm)	L_1 (mm)	S (mm)
4	59.5	37	8.3
5	64.0	42	12.4

Morse Taper Socket



Morse Taper No.	A (mm)	L (mm)	M (mm)	N (mm)	K (mm)	S (mm)	Taper per mm. on dia.	Included Angle Deg.	Min.	Sec.
0	9.045	63.5	52.5	6.4	49.2	4.4	0.05205	2	58	54
1	12.065	70.0	55.5	9.4	52.4	5.5	0.04988	2	51	27
2	17.780	84.5	75.5	14.5	63.5	6.7	0.04995	2	51	41
3	23.825	105.0	83.5	19.8	77.8	8.3	0.05020	2	52	31
4	31.267	140.0	105.5	25.9	98.4	12.3	0.05194	2	58	31
5	44.399	165.0	132.0	37.4	125.4	16.6	0.05263	3	0	52
6	63.348	227.0	187.5	53.6	177.8	19.8	0.05214	2	59	12
7	83.058	308.0	258.0	69.8	241.4	29.4	0.05200	2	56	44

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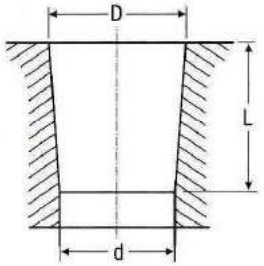
DIMENSIONS OF JACOBS & DIN TAPERS FOR DRILL CHUCKS (For Identification Purposes)



Jacobs Taper

Jacobs Taper No.	D (mm)	d (mm)	L (mm)	Taper per mm on Dia.	Included Angle (Approx.) Deg.	Min.
0	6.350	5.802	11.112	0.04929	2	49
1	9.754	8.469	16.669	0.07709	4	24
2 short	13.940	12.386	19.050	0.08155	4	39
2	14.199	12.386	22.225	0.08155	4	39
33	15.850	14.237	25.400	0.06350	3	38
6	17.170	15.852	25.400	0.05191	2	58
3	20.599	18.951	30.956	0.05325	3	02
4	28.550	26.346	42.049	0.05241	2	59
5	35.890	32.422	47.625	0.05168	2	58

DIN Taper

DIN Taper No.	Morse Taper No.	D (mm)	d (mm)	L (mm)	Taper per mm on Dia.	Included Angle Deg.	Min.	Sec.
B10	1	10.094	9.4	14.5	0.04988	2	51	27
B12	1	12.065	11.1	18.5	0.04988	2	51	27
B16	2	15.733	14.5	24.0	0.04995	2	51	41
B18	2	17.780	16.2	32.0	0.04995	2	51	41
B22	3	21.793	19.8	40.5	0.05020	2	52	31
B24	3	23.825	21.3	50.5	0.05020	2	52	31

NOTE: DIN Tapered Sections are identical with the following Morse Tapers :

B10 & B12 for Morse Taper No. 1

B16 & B18 for Morse Taper No. 2

B22 & B24 for Morse Taper No. 3

The length of each of these tapers is less than the overall length of the corresponding Morse Taper. Each taper may be regarded as corresponding approximately either to that part of the Morse Taper nearest the smaller end, e.g. B10 or to the part nearest to the large end, e.g. B12.

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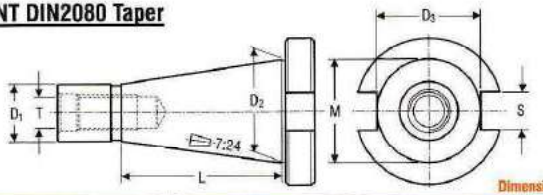
PRINCIPAL DIMENSIONS OF MILLING M/C ARBORS/SHANKS (For Identification Purposes)

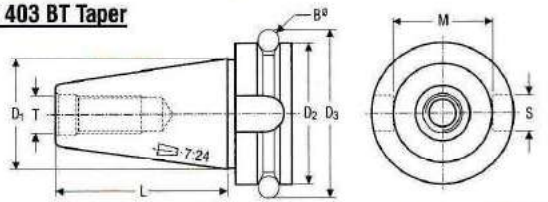
ISO/NT DIN2080 Taper



Dimensions in mm

ISO/NT	D1	D2	D3	L	M	S	T (thread)	
							Metric	Inch
30	17.4	31.75	50.0	48.4	32.4	16.1	M12	1/2" UNC
40	25.3	44.45	63.0	65.4	45.0	16.1	M16	5/8" UNC
45	32.4	57.15	80.0	82.8	58.0	19.3	M20	3/4" UNC
50	39.6	69.85	97.5	101.8	70.6	25.7	M24	1" UNC
60	60.2	107.95	156.0	161.8	120.0	25.7	M30	1 1/4" UNC

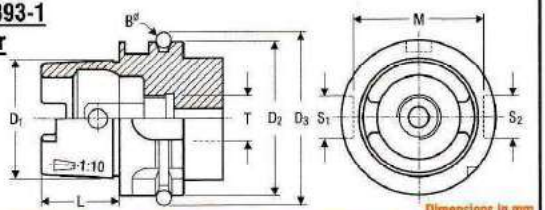
MAS 403 BT Taper



Dimensions in mm

MAS/BT	D1	D2	D3	Bø	L	M	S	T (thread)
30	31.75	46	56.14	8	48.4	32.6	16.1	M12
35	38.10	53	65.68	10	56.4	39.2	16.1	M12
40	44.45	63	75.68	10	65.4	45.2	16.1	M16
45	57.15	85	100.21	12	82.8	58.2	19.3	M20
50	69.85	100	119.02	15	101.8	70.8	25.7	M24

HSK DIN 69893-1 Form A Taper



Dimensions in mm

HSK	D1	D2	D3	Bø	L	M	S1	S2	T (thread)
32	24	32	37.0	4	16	26	9	7	M10 x 1.0
40	30	40	45.0	4	20	34	11	9	M12 x 1.0
50	38	50	59.3	7	25	42	14	12	M16 x 1.0
63	48	63	72.3	7	32	53	18	16	M18 x 1.0
80	60	80	88.8	7	40	68	20	18	M20 x 1.5
100	75	100	109.7	7	50	88	22	20	M24 x 1.5

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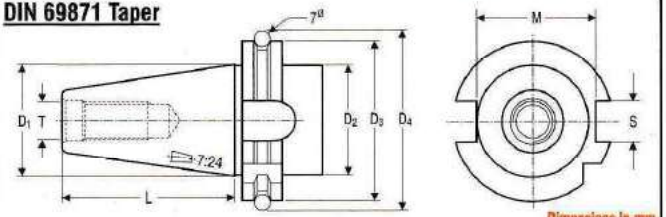
PRINCIPAL DIMENSIONS OF MILLING M/C ARBORS/SHANKS (For Identification Purposes)

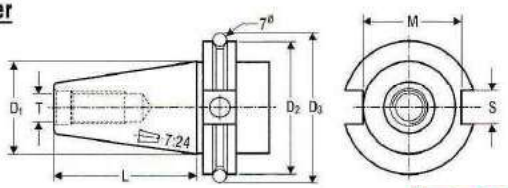
DIN 69871 Taper



Dimensions in mm

DIN	D1	D2	D3	D4	L	M	S	T (thread)
30	31.75	45	50.00	59.30	47.8	35.4	16.1	M12
40	44.45	50	63.55	72.30	68.4	47.8	16.1	M16
45	57.15	63	82.55	91.35	82.7	60.4	19.3	M20
50	69.82	80	97.50	107.25	101.7	73.2	25.7	M24

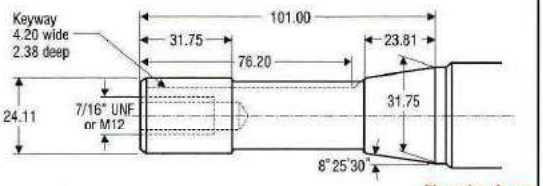
ANSI/CAT Taper



Dimensions in mm

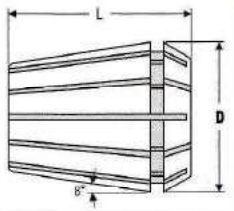
ANSI/CAT	D1	D2	D3	L	M	S	T (thread)	
							Metric	Inch
40	44.45	63.55	72.30	68.4	48.8	16.1	M16	5/8" UNC
45	57.15	82.55	91.35	82.7	61.6	19.3	M20	3/4" UNC
50	69.85	98.45	107.25	101.7	75.9	25.7	M24	1" UNC

R8 Taper



Dimensions in mm

ER Collets



Type	Size Range	D	L	Number of Collets in Set
ER 8	0.5 - 5.0	8.5	13.5	9
ER 11	0.5 - 7.0	11.5	18.0	13
ER 16	0.5 - 10.0	17.0	27.5	13
ER 20	1.0 - 13.0	21.0	31.5	16
ER 25	1.0 - 16.0	26.0	34.0	21
ER 32	2.0 - 20.0	33.0	40.0	23
ER 40	3.0 - 26.0	41.0	46.0	28
ER 50	5.0 - 34.0	52.0	60.0	17

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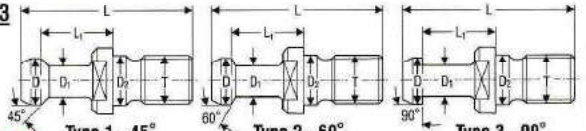
STANDARD PULL STUDS/RETENTION KNOBS
(For Identification Purposes)

MAS 403 BT



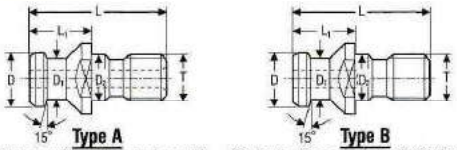
Type 1 - 45° | Type 2 - 60° | Type 3 - 90°

Dimensions in mm

Taper	D	D1	D2	L	L1	T (thread)
30	11	7	16.5	43	18	M12
40	15	10	23.0	60	28	M16
50	23	17	38.0	85	35	M24

Specify:
- Taper No.
- Type
- With/without through coolant hole
- With/without O Ring

DIN 69872



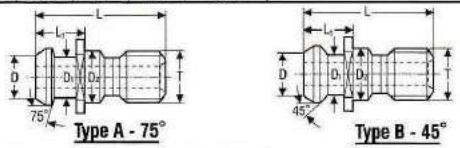
Type A (For tools with axial coolant supply) | Type B (For tools with coolant supply via the flange)

Dimensions in mm

Taper	D	D1	D2	L	L1	T (thread)
30	13	9	13	44	24	M12
40	19	14	17	54	26	M16
45	23	17	21	65	30	M20
50	28	21	25	74	34	M24

Specify:
- Taper No.
- Type
- With/without through coolant hole
- With/without O Ring

ISO 7388/2 (DIN 69871/A)



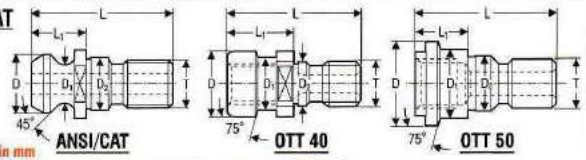
Type A - 75° | Type B - 45°

Dimensions in mm

Taper	Type	D	D1	D2	L	L1	T (thread)
40	A	19.0	14.0	17	54.0	26.0	M16
	B	18.9	12.9	17	44.5	16.4	M16
45	A	23.0	17.0	21	65.0	30.0	M20
	B	24.0	16.3	21	56.0	20.9	M20
50	A	28.0	21.0	25	74.0	34.0	M24
	B	29.0	19.6	25	65.5	25.5	M24

Specify:
- Taper No.
- Type
- With/without through coolant hole
- With/without O Ring

ANSI/CAT OTT



ANSI/CAT | OTT 40 | OTT 50

Dimensions in mm

Taper	D	D1	D2	L	L1	T (thread)
ANSI/CAT 40	18.95	12.95	17	16.40	44.5	M16
ANSI/CAT 45	24.05	16.30	21	20.95	56.0	M20
ANSI/CAT 50	29.10	19.60	25	25.55	65.5	M24
OTT 40	25.00	21.1	17	53.0	25.0	M16
OTT 50	39.50	32.0	25	65.3	25.2	M24

Specify:
- Taper No.
- With/without through coolant hole
- With/without O Ring

Engineers Black Book - 2nd Edition

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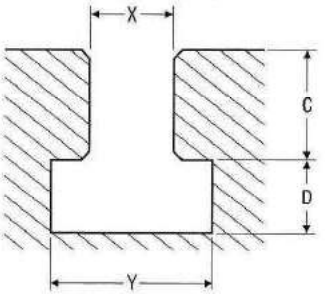
STANDARD T-SLOTS

Standard METRIC & INCH T-Slots



Metric T-Slots

Dimensions in mm

Nominal T-Bolt Size	'X' Min.	'X' Max.	'Y' Min.	'Y' Max.	'C' Min.	'C' Max.	'D' Min.	'D' Max.
6 mm	8.00	8.15	14.50	16.00	7.00	11.00	7.00	8.00
8 mm	10.00	10.15	16.00	18.00	9.00	14.00	7.00	8.00
10 mm	12.00	12.18	19.00	21.00	11.00	17.00	8.00	9.00
12 mm	14.00	14.18	23.00	25.00	12.00	19.00	9.00	11.00
16 mm	18.00	18.21	30.00	32.00	16.00	24.00	12.00	14.00
20 mm	22.00	22.21	37.00	40.00	20.00	29.00	16.00	18.00
24 mm	28.00	28.21	46.00	50.00	26.00	36.00	20.00	22.00
30 mm	36.00	36.25	56.00	60.00	33.00	46.00	25.00	28.00
36 mm	42.00	42.25	68.00	72.00	39.00	53.00	32.00	35.00

Inch T-Slots

Dimensions in inches

Nominal T-Bolt Size	'X' Min.	'X' Max.	'Y' Min.	'Y' Max.	'C' Min.	'C' Max.	'D' Min.	'D' Max.
1/4"	.282	.292	.500	.562	.125	.375	.203	.234
5/16"	.344	.354	.594	.656	.156	.438	.234	.266
3/8"	.438	.448	.719	.781	.219	.562	.297	.328
1/2"	.562	.572	.906	.969	.312	.688	.359	.391
5/8"	.688	.698	1.188	1.250	.438	.875	.453	.484
3/4"	.812	.822	1.375	1.469	.562	1.062	.594	.625
1"	1.062	1.072	1.750	1.844	.750	1.250	.781	.828
1 1/4"	1.312	1.322	2.125	2.219	1.000	1.562	1.031	1.094
1 1/2"	1.562	1.572	2.562	2.656	1.250	1.938	1.281	1.344

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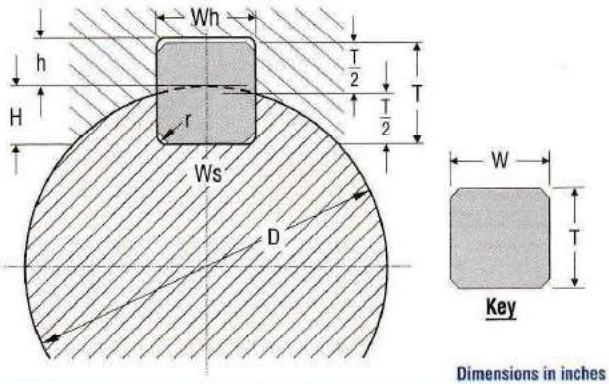
INCH SQUARE PARALLEL KEYS & KEYWAYS (B.S. 46 : PART 1 : 1958)



Dimensions in inches

Nominal Shaft Dia. (D)		Key		Keyway in Shaft		Keyway in Hole (Bore)		Keyway Radius Max. (r)
Over	Up to & including	Key Size (Square) (W x T)	Width / Thickness	Width (Ws)	Depth (H)	Width (Wh)	Depth (h)	
1/4	1/2	1/8	0.127 0.125	0.125 0.124	0.078 0.072	0.126 0.125	0.066 0.060	0.010
1/2	3/4	3/16	0.190 0.188	0.188 0.187	0.113 0.107	0.189 0.188	0.094 0.088	0.010
3/4	1	1/4	0.252 0.250	0.250 0.249	0.148 0.142	0.251 0.250	0.121 0.115	0.010
1	1 1/4	5/16	0.314 0.312	0.312 0.311	0.183 0.177	0.313 0.312	0.148 0.142	0.010
1 1/4	1 1/2	3/8	0.377 0.375	0.375 0.374	0.219 0.213	0.376 0.375	0.175 0.169	0.010
1 1/2	1 3/4	7/16	0.440 0.438	0.438 0.437	0.254 0.248	0.439 0.438	0.203 0.197	0.020
1 3/4	2	1/2	0.502 0.500	0.500 0.499	0.289 0.283	0.501 0.500	0.230 0.224	0.020
2	2 1/2	5/8	0.627 0.625	0.625 0.624	0.360 0.354	0.626 0.625	0.284 0.278	0.020
2 1/2	3	3/4	0.752 0.750	0.750 0.749	0.430 0.424	0.751 0.750	0.339 0.333	0.020
3	3 1/2	7/8	0.877 0.875	0.875 0.874	0.501 0.495	0.876 0.875	0.393 0.387	0.062
3 1/2	4	1	1.003 1.000	1.000 0.999	0.572 0.566	1.001 1.000	0.448 0.442	0.062
4	5	1 1/4	1.253 1.250	1.250 1.248	0.713 0.707	1.252 1.250	0.557 0.551	0.062
5	6	1 1/2	1.504 1.500	1.500 1.498	0.854 0.848	1.502 1.500	0.667 0.661	0.062

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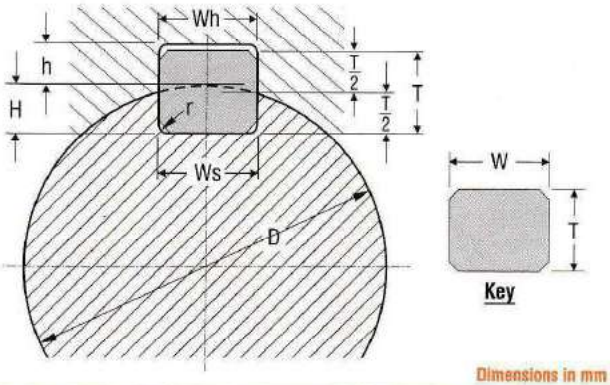
METRIC SQUARE & RECTANGULAR PARALLEL KEYS & KEYWAYS (B.S. 4235 : PART 1 : 1972)



Dimensions in mm

Nominal Shaft Dia. (D)		Key			Keyway in Shaft		Keyway in Hole (Bore)		Keyway Radius Max. (r)
Over	Up to & including	Key Size (W x T)	Width (W)	Thickness (T)	Width (Ws)	Depth (H)	Width (Wh)	Depth (h)	
10	12	4 x 4	4.030 3.970	4.030 3.970	4.000 3.970	2.60 2.50	4.015 3.985	1.90 1.80	0.16
12	17	5 x 5	5.030 4.970	5.030 4.970	5.000 4.970	3.10 3.00	5.015 4.985	2.40 2.30	0.25
17	22	6 x 6	6.030 5.970	6.030 5.970	6.000 5.970	3.60 3.50	6.015 5.985	2.90 2.80	0.25
22	30	8 x 7	8.000 7.964	7.000 6.910	8.000 7.964	4.20 4.00	8.018 7.982	3.50 3.30	0.25
30	38	10 x 8	10.000 9.964	8.000 7.910	10.000 9.964	5.20 5.00	10.018 9.982	3.50 3.30	0.40
38	44	12 x 8	12.000 11.957	8.000 7.910	12.000 11.957	5.20 5.00	12.021 11.979	3.50 3.30	0.40
44	50	14 x 9	14.000 13.957	9.000 8.910	14.000 13.957	5.70 5.50	14.021 13.979	4.00 3.80	0.40
50	58	16 x 10	16.000 15.957	10.000 9.910	16.000 15.957	6.20 6.00	16.021 15.979	4.50 4.30	0.40
58	65	18 x 11	18.000 17.957	11.000 10.890	18.000 17.957	7.20 7.00	18.021 17.979	4.60 4.40	0.40
65	75	20 x 12	20.000 19.948	12.000 11.890	20.000 19.948	7.70 7.50	20.026 19.974	5.10 4.90	0.60
75	85	22 x 14	22.000 21.948	14.000 13.890	22.000 21.948	9.20 9.00	22.026 21.974	5.60 5.40	0.60
85	95	25 x 14	25.000 24.948	14.000 13.890	25.000 24.948	9.20 9.00	25.026 24.974	5.60 5.40	0.60
95	110	28 x 16	28.000 27.948	16.000 15.890	28.000 27.948	10.20 10.00	28.026 27.974	6.60 6.40	0.60

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KEYWAY FORMULAE

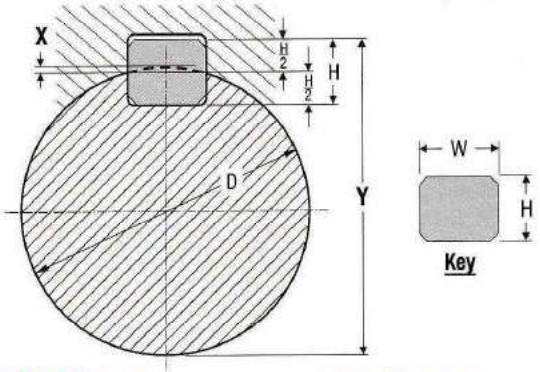
Milling Keyways

To calculate "Y" (total measurement from top of key to bottom of shaft)

$$X = \tfrac{1}{2}\left(D - \sqrt{D^2 - W^2}\right) \qquad \text{Also } X = \frac{W^2}{4 \times D}\left(\begin{array}{l}\text{Approx. within}\\ 0.05\text{ mm / .002"}\end{array}\right)$$

$$Y = D + H - \left(\frac{H}{2} + X\right)$$

D = Shaft diameter
W = Width of key
H = Key height



Key

Metric Keyways

Dimensions in mm

Diameter of Shaft (D)	Key Size (W x H)	Dimension X	Dimension Y
8	3 x 3	.2919	9.2081
10	4 x 4	.4174	11.5826
12	4 x 4	.3431	13.6569
14	5 x 5	.4617	16.0383
16	5 x 5	.4007	18.0993
18	6 x 6	.5147	20.4853
20	6 x 6	.4606	22.5394
22	6 x 6	.4170	24.5830
25	8 x 7	.6573	27.8427
28	8 x 7	.5836	30.9164
30	8 x 7	.5432	32.9568
35	10 x 8	.7295	38.2705
40	12 x 8	.9212	43.0788
50	14 x 9	1.0000	53.5000
60	18 x 11	1.3818	64.1182
70	20 x 12	1.4590	74.5410
80	22 x 14	1.5422	85.4578
100	28 x 16	2.0000	106.0000

Inch Keyways

Dimensions in inches

Diameter of Shaft (D)	Key Size (Square) (W x H)	Dimension X	Dimension Y
5/16	3/32	.0072	.3522
3/8	1/8	.0107	.4268
7/16	1/8	.0091	.4909
1/2	1/8	.0079	.5546
5/8	3/16	.0144	.7044
3/4	3/16	.0119	.8319
7/8	3/16	.0102	.9585
1	1/4	.0159	1.1093
1 1/8	5/16	.0221	1.2592
1 1/4	5/16	.0198	1.3865
1 3/8	3/8	.0261	1.5364
1 1/2	3/8	.0238	1.6637
1 3/4	7/16	.0278	1.9410
2	1/2	.0318	2.2182
2 1/4	5/8	.0443	2.5182
2 1/2	5/8	.0397	2.7728
2 3/4	3/4	.0521	3.0729
3	3/4	.0476	3.3274

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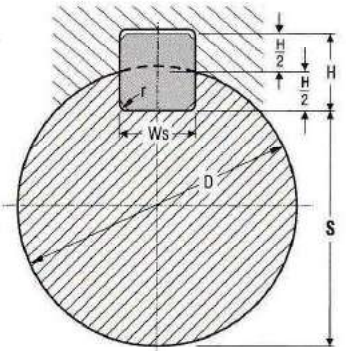
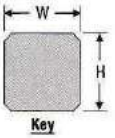
INCH SQUARE (PREFERRED) PARALLEL KEYS & KEYWAYS (ANSI B17.1-1967, R1989)





Key

Class 1 - Side Fit

Dimensions in inches

Nominal Shaft Dia. (D)		Key		Keyway in Shaft		Keyway Radius Max. (r)
Over	Up to & including	Key Size (Square) (W x H)	Width / Thickness	Width (Ws)	Nominal Depth (H/2)	
5/16	7/16	3/32	0.093 0.091	0.095 0.093	3/64	1/32
7/16	9/16	1/8	0.125 0.123	0.127 0.125	1/16	1/32
9/16	7/8	3/16	0.187 0.185	0.189 0.187	3/32	1/32
7/8	1 1/4	1/4	0.250 0.248	0.252 0.250	1/8	1/32
1 1/4	1 3/8	5/16	0.312 0.310	0.314 0.312	5/32	1/32
1 3/8	1 3/4	3/8	0.375 0.373	0.377 0.375	3/16	1/32
1 3/4	2 1/4	1/2	0.500 0.498	0.502 0.500	1/4	1/32
2 1/4	2 3/4	5/8	0.625 0.623	0.628 0.625	5/16	1/16
2 3/4	3 1/4	3/4	0.750 0.747	0.753 0.750	3/8	1/16
3 1/4	3 3/4	7/8	0.875 0.872	0.878 0.875	7/16	1/16
3 3/4	4 1/2	1	1.000 0.997	1.003 1.000	1/2	1/16
4 1/2	5 1/2	1 1/4	1.250 1.247	1.254 1.250	5/8	1/8
5 1/2	6 1/2	1 1/2	1.500 1.497	1.504 1.500	3/4	1/8

Measurement from bottom of Keyseat	
Nominal Shaft Dia. (D)	(S)
1/2"	0.430
9/16"	0.493
5/8"	0.517
11/16"	0.581
3/4"	0.644
13/16"	0.708
7/8"	0.771
15/16"	0.796
1"	0.859
1 1/16"	0.923
1 1/8"	0.986
1 3/16"	1.049
1 1/4"	1.112
1 5/16"	1.137
1 3/8"	1.201
1 7/16"	1.225
1 1/2"	1.289
1 5/8"	1.416
1 3/4"	1.542
1 7/8"	1.591
2"	1.718
2 1/8"	1.845
2 1/4"	1.972
2 3/8"	2.021
2 1/2"	2.148
3"	2.577

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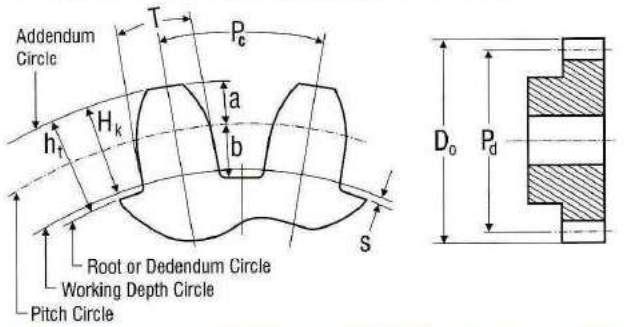
FORMULAE FOR SPUR GEAR CALCULATIONS



To Find	Formula
Diametral pitch P	$P = \frac{3.1416}{P_c} = \frac{N}{P_d} = \frac{25.4}{\text{Module}}$
Module (mm)	$= \frac{25.4}{P} = \frac{P_d\,(\text{mm})}{N}$
Circular pitch (inch) P_c	$P_c = \frac{3.1416}{P} = \frac{3.1416 \times P_d}{N}$
Circular pitch (mm) P_c	$P_{c\,(mm)} = 3.1416 \times \text{Module}$
Pitch diameter (inch) P_d	$P_d = \frac{N}{P} = \frac{N \times P_c}{3.1416}$
Pitch diameter (mm) P_d	$P_{d\,(mm)} = N \times \text{Module}$
Outside dia. (inch/mm) D_o	$D_o = \frac{N+2}{P} = P_d + 2a$
Number of teeth in the gear N	$N = P_d \times P = \frac{3.1416 \times P_d}{P_c}$
Center distance C	$C = \frac{N_1 + N_2}{2P}$
Length of rack L	$L = N \times P_c$

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TOOTH PARTS - FULL DEPTH TEETH, METRIC MODULE & STUB TOOTH GEARING

Tooth Parts – Full Depth Teeth

To Find		20° Pressure Angle	14½° Pressure Angle
Addendum	a	1.00 ÷ P	1.000 ÷ P
Minimum dedendum	b	1.25 ÷ P	1.157 ÷ P
Working depth	h_k	2.00 ÷ P	2.000 ÷ P
Minimum whole depth	h_t	2.25 ÷ P	2.157 ÷ P
Basic circular tooth thickness at pitch line	T	1.5708 ÷ P	1.5708 ÷ P
Minimum clearance	S	.25 ÷ P	.157 ÷ P

Tooth Parts Metric Module System – Pressure Angle = 20° Dimensions in mm

Addendum	a	a	=	1 x	Module
Minimum dedendum	b	b	=	1.25 x	Module
Working depth	h_k	h_k	=	2 x	Module
Minimum whole depth	h_t	h_t	=	2.25 x	Module
Basic circular tooth thickness at pitch line	T	T	=	1.5708 x	Module
Minimum clearance	S	S	=	.25 x	Module

Tooth Parts – Stub Tooth gearing – Pressure Angle = 20°

To Find		American	Fellows	Nuttal
Addendum	a	.800 ÷ P	1.000 ÷ P_s	.250 x P_c
Minimum dedendum	b	1.000 ÷ P	1.250 ÷ P_s	.300 x P_c
Working depth	h_k	1.600 ÷ P	2.000 ÷ P_s	.500 x P_c
Minimum whole depth	h_t	1.800 ÷ P	2.250 ÷ P_s	.550 x P_c
Basic circular tooth thickness at pitch line	T	1.5708 ÷ P	1.5708 ÷ P_s	.500 x P_c
Minimum clearance	S	.200 ÷ P	.250 ÷ P_s	.050 x P_c

P_s = Stub diametral pitch, e.g. **"8"** in 6/8 DP

SPUR GEARING
TABLE OF EQUIVALENT PITCHES

Diametral Pitch	Circular Pitch (in.)	Module mm.	Diametral Pitch	Circular Pitch (in.)	Module mm.	Diametral Pitch	Circular Pitch (in.)	Module mm.
1	3.1416	25.4000	2.7925	1 1/8	9.0957	8.4667	0.3711	3
1.0160	3.0921	25	2.8222	1.1132	9	9	0.3491	2.8222
1.0472	3	24.2552	3	1.0472	8.4667	10	0.3142	2.5400
1.1424	2 3/4	22.2339	3.1416	1	8.0851	10.0531	5/16	2.5266
1 1/4	2.5133	20.3202	3.1750	0.9895	8	10.1600	0.3092	2.5000
1.2566	2 1/2	20.2127	3.3510	15/16	7.5797	11	0.2856	2.3091
1.2700	2.4737	20	3 1/2	0.8976	7.2571	12	0.2618	2.1167
1.3963	2 1/4	18.1914	3.5904	7/8	7.0744	12.5664	1/4	2.0213
1.4111	2.2263	18	3.6286	0.8658	7	12.7000	0.2474	2
1 1/2	2.0944	16.9333	3.8666	13/16	6.5691	13	0.2417	1.9538
1.5708	2	16.1701	3.9078	0.8040	6.5000	14	0.2244	1.8143
1.5875	1.9790	16	4	0.7854	6.3500	15	0.2094	1.6933
1.6755	1 7/8	15.1595	4.1888	3/4	6.0638	16	0.1963	1.5875
1.6933	1.8553	15	4.2333	0.7421	6	16.7552	3/16	1.5159
1 3/4	1.7952	14.5143	4.5696	11/16	5.5585	16.9333	0.1855	1.5000
1.7952	1 3/4	14.1489	4.6182	0.6803	5.5000	17	0.1848	1.4941
1.8143	1.7316	14	5	0.6283	5.0800	18	0.1745	1.4111
1.9333	1 5/8	13.1382	5.0265	5/8	5.0532	19	0.1653	1.3368
1.9538	1.6079	13	5.0800	0.6184	5	20	0.1571	1.2700
2	1.5708	12.7000	5.5851	9/16	4.5478	22	0.1428	1.1545
2.0944	1 1/2	12.1276	5.6443	0.5566	4.5000	24	0.1309	1.0583
2.1167	1.4842	12	6	0.5236	4.2333	25	0.1257	1.0160
2 1/4	1.3963	11.2892	6.2832	1/2	4.0425	25.1327	1/8	1.0106
2.2848	1 3/8	11.1170	6.3500	0.4947	4	25.4000	0.1237	1
2.3091	1.3605	11	7	0.4488	3.6286	26	0.1208	0.9769
2 1/2	1.2566	10.1600	7.1808	7/16	3.5372	28	0.1122	0.9071
2.5133	1 1/4	10.1062	7.2571	0.4329	3.5000	30	0.1047	0.8467
2.5400	1.2368	10	8	0.3927	3.1750			
2 3/4	1.1424	9.2364	8.3776	3/8	3.0319			

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CALCULATION OF SPINDLE SPEEDS / NUMBER OF TEETH IN BELT / GEAR DRIVES

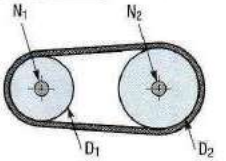
Belt Drive

Diameter x rpm of Driving Pulley = Diameter x rpm of Driven Pulley

$$D_1 \times N_1 = D_2 \times N_2$$

D_1 & D_3 = Diameters of Driving Pulleys
D_2 & D_4 = Diameters of Driven Pulleys
N_1 & N_3 = Speed(rpm) of Driving Pulleys
N_2 & N_4 = Speed(rpm) of Driven Pulleys

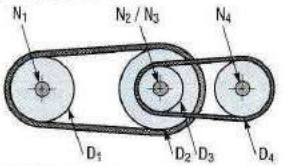
Single Drive



$$D_1 = \frac{D_2 \times N_2}{N_1} \qquad N_1 = \frac{D_2 \times N_2}{D_1}$$

$$D_2 = \frac{D_1 \times N_1}{N_2} \qquad N_2 = \frac{D_1 \times N_1}{D_2}$$

Compound Drive



$$N_4 = N_1 \times \frac{D_1}{D_2} \times \frac{D_3}{D_4}$$

Note : Speed(rpm) N_2 always = Speed(rpm) N_3

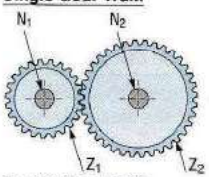
Gear Drive

No. of Teeth x rpm of Driving Gear = No. of Teeth x rpm of Driven Gear

$$Z_1 \times N_1 = Z_2 \times N_2$$

Z_1 & Z_3 = No of Teeth in Driving Gear
Z_2 & Z_4 = No of Teeth in Driven Gear
N_1 & N_3 = Speed(rpm) of Driving Gear
N_2 & N_4 = Speed(rpm) of Driven Gear

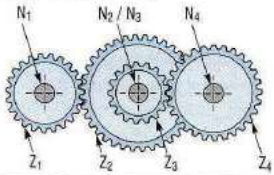
Single Gear Train



$$Z_1 = \frac{Z_2 \times N_2}{N_1} \qquad N_1 = \frac{Z_2 \times N_2}{Z_1}$$

$$Z_2 = \frac{Z_1 \times N_1}{N_2} \qquad N_2 = \frac{Z_1 \times N_1}{Z_2}$$

Double Gear Train



$$N_4 = N_1 \times \frac{Z_1}{Z_2} \times \frac{Z_3}{Z_4}$$

Note : Speed(rpm) N_2 always = Speed(rpm) N_3

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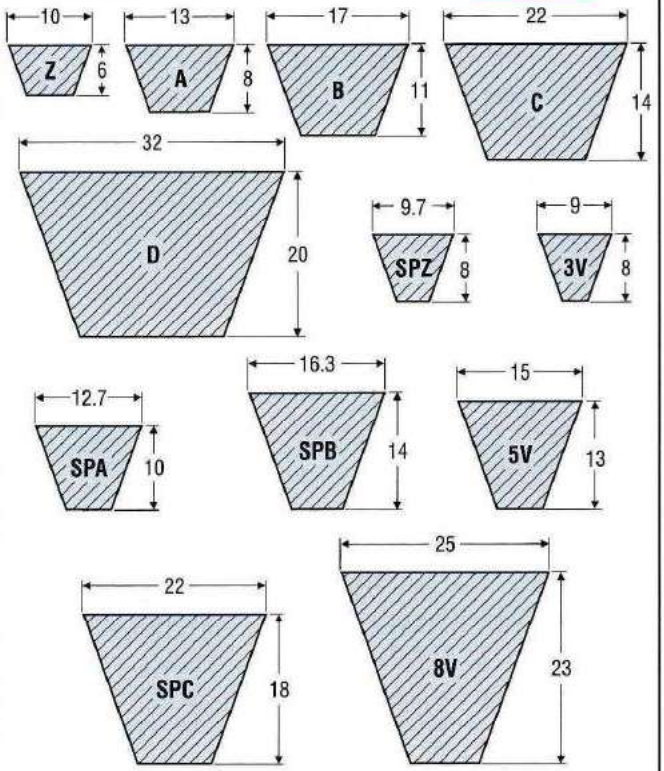
V-BELTS CROSS SECTION DIMENSIONS

Conventional & Narrow Section V-Belts *(Actual Size)*



NOTE : See Comparison Chart on page 89 for other Equivalent Symbols

Calculation of Pitch Length

Section	Pitch Length exceeds inside length by mm.
Z	25
A	33
B	43
C	62
D	82
SPZ/3V	42
SPA	46
SPB/5V	71
SPC	87

Centre Distance Calculation

To determine belt length required given pulley diameters and centre distance, use the following formula :

$$L = 2C + \frac{(D-d)^2}{4C} + 1.57\,(D+d)$$

where

- **L** = Pitch length of belt in millimetres.
- **C** = Centre distance in millimetres.
- **D** = Pitch diameter of large pulley in millimetres.
- **d** = Pitch diameter of small pulley in millimetres.

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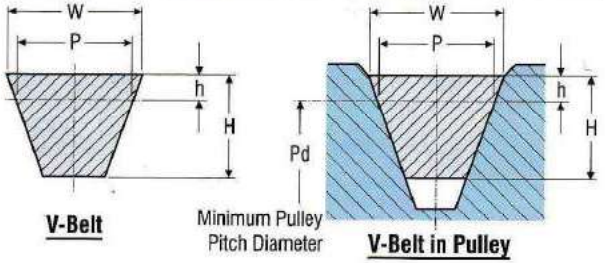
V-BELTS CROSS SECTION DIMENSIONS & COMPARISON CHART

Conventional & Narrow Section V-Belts (Dimensional Data)

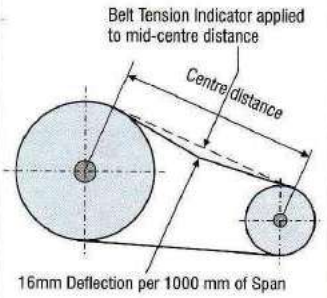


Comparison Chart

Dimensions in mm

BS/ISO	Z (ZX)	A (AX)	B (BX)	C (CX)	D (DX)	SPZ (XPZ)		SPA (XPA)	SPB (XPB)		SPC (XPC)	
DIN	10 (X10)	13 (X13)	17 (X17)	22 (X22)	32 (X32)	SPZ (XPZ)		SPA (XPA)	SPB (XPB)		SPC (XPC)	
RMA/MPTA		A (AX)	B (BX)	C (CX)	D (DX)		3V (3VX)			5V (5VX)		8V (8VX)
Top of Belt Width [W]	10	13	17	22	32	9.7	9.0	12.7	16.3	15	22	25
Pitch Width [P]	8.5	11	14	19	27	8.5	8.5	11	14	14	19	23.5
Height of Belt [H]	6	8	11	14	20	8	8	10	14	13	18	23
Pitch Height [h]	2	2.8	4.2	5.7	6.9	2	2	2.8	4.2	4.2	5.7	3.2
Min. Pulley Pitch Dia. [Pd]	50 (40)	71 (63)	112 (90)	180 (140)	355 (250)	63 (56)	63 (56)	90 (71)	140 (112)	140 (112)	224 (180)	315
Max. Belt Speed m/s	30	30	30	30	30	40	40	40	40	40	40	40

Tensioning Forces



Belt Section	Force required to deflect belt 16 mm per metre of span		
	Small Pulley Dia. (mm)	Newton (N)	Kilogram-force (kgf)
Z	56 to 100	5 to 7.5	0.5 to 0.8
A	80 to 140	10 to15	1.0 to 1.5
B	125 to 200	20 to 30	2.0 to 3.1
C	200 to 400	40 to 60	4.1 to 6.1
D	355 to 600	70 to 105	7.1 to 10.7
SPZ/3V	56 to 95	13 to 20	1.3 to 2.0
	100 to 140	20 to 25	2.0 to 2.5
SPA	80 to 132	25 to 35	2.5 to 3.6
	140 to 200	35 to 45	3.6 to 4.6
SPB/5V	112 to 224	45 to 65	4.6 to 6.6
	236 to 315	65 to 85	6.6 to 8.7
SPC	224 to 355	85 to 115	8.7 to 11.7
	375 to 560	115 to 150	11.7 to 15.3

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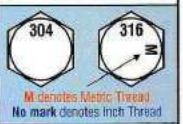
COMMON WORKSHOP BOLTS IDENTIFICATION & MECHANICAL PROPERTIES

Common METRIC Steel Bolts

Identification Mark					
Product Specification	**Class 4.6**	**Class 5.8**	**Class 8.8**	**Class 10.9**	**Class 12.9 Socket Head Cap Screws**
Material	Low/Medium Carbon Steel	Low/Medium Carbon Steel Heat Treated	Medium Carbon Steel Heat Treated	Alloy Steel Heat Treated	Alloy Steel Heat Treated
Tensile Strength Minimum	400 Mpa (58000 psi)	520 Mpa (75000 psi)	830 Mpa (120000 psi)	1040 Mpa (150000 psi)	1220 Mpa (176000 psi)
Yield Strength Minimum	240 Mpa	420 Mpa	640 Mpa	940 Mpa	1100 Mpa
Proof Load	220 Mpa	380 Mpa	600 Mpa	830 Mpa	970 Mpa
Hardness Min	HRB-67	HRB-82	HRC-22	HRC-32	HRC-39
Max	HRB-95	HRB-95	HRC-34	HRC-39	HRC-44
Compatible Nut	Class 5	Class 5	Class 8	Class 10	–

Common INCH Steel Bolts — Stainless Steel

Identification Mark						
Product Specifications	**Grade 2**	**Grade 5**	**Grade 8**	**Soc. Hd. Cap Scrs.**	**Stainless Steel**	**Stainless Steel**
Nominal Size Range	1/4 - 3/4 (>3/4-1 1/2)	1/4-1 (>1-1 1/2)	1/4 -1 1/2	<1/2 (>1/2 -2)	–	–
Material	Low/Med. Carbon Steel	Medium Carb. Steel Heat Treated	Medium Carb. Steel Heat Treated	Alloy Steel Heat Treated	Stainless Steel 304	Stainless Steel 316
Tensile Strength Minimum [psi]	74000 (60000)	120000 (105000)	150000	180000 (170000)	85000	85000
Yield Strength Minimum [psi]	57000 (36000)	91000 (81000)	130000	162000 (153000)	35000	35000
Proof Load [psi]	55000 (33000)	85000 (74000)	120000	140000 (135000)	–	–
Hardness Min	HRB-70	HRC-19	HRC-33	HRC-38	HRB-80	HRB-80
Max	HRB-95	HRC-34	HRC-39	HRC-45		
Compatible Nut	Mild Steel	Grade 5	Grade 8	–	304	316

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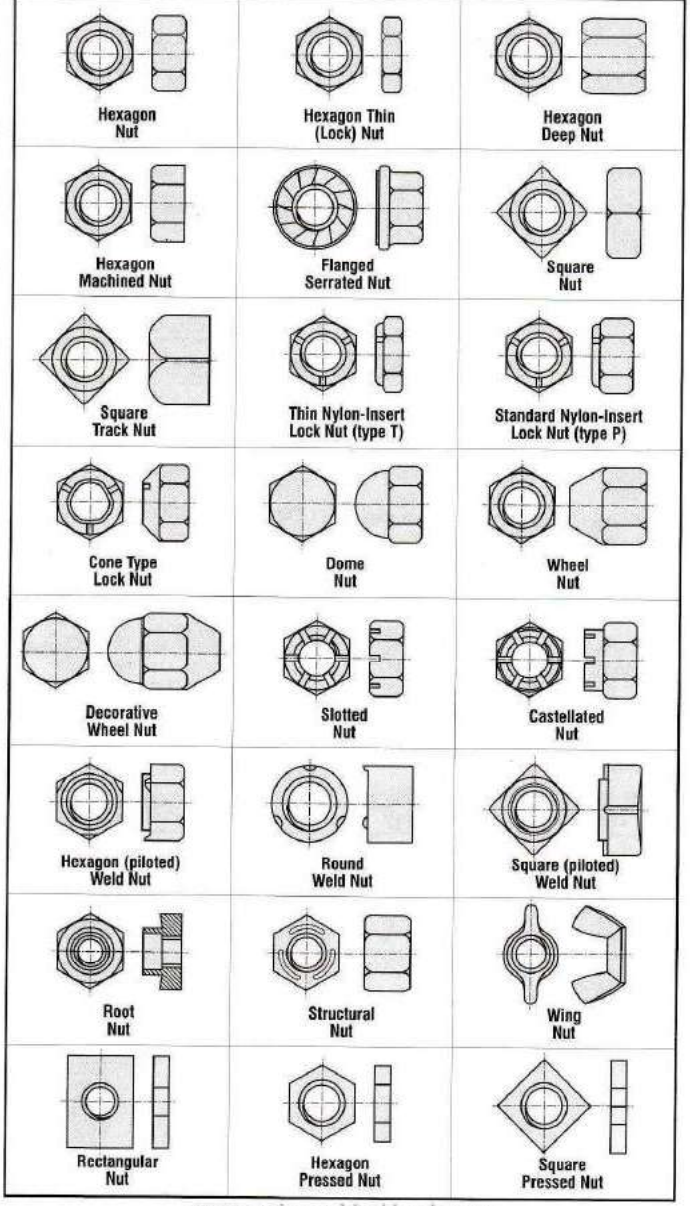
COMMON WORKSHOP NUTS



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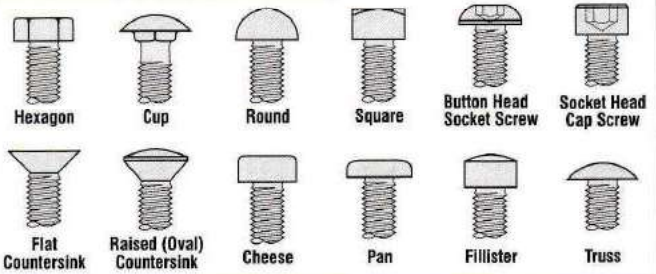
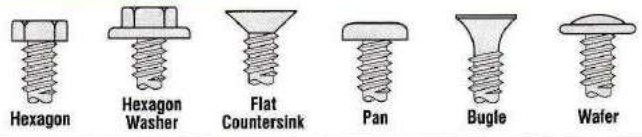
COMMON BOLT & SCREW – HEADS & TYPES

Bolt & Screw Heads (Metal Threads)



Self-Threading Screw Heads & Points



Type A	Type AB	Type B / Type Z	Type 17
Use : Sheet metal applications.	Use : Sheet metal applications.	Use : Shallow holes in composite materials.	Use : Self-drilling in thin metals.
Type T / Type 23	**Type BT / Type 25**	**Needle Point**	**Drill Point**
Use : Soft metal castings.	Use : Plastics & composites	Use : Piercing Light metals.	Use : Self drilling applications.

Socket Set-Screw Points

Socket Set Screw	Cup Point	Oval Point	Dog Point
	Use : Against hardened shafts.	Use : For frequent adjustment.	Use : For permanent location.
Half Dog Point	**Cone Point**	**Flat Point**	**Knurled Cup Point**
Use : For permanent location.	Use : For permanent location.	Use : Where parts must be often reset.	Use : For permanent location.

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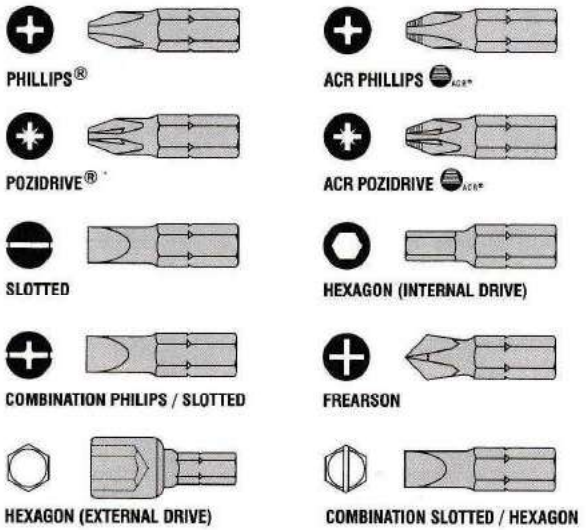
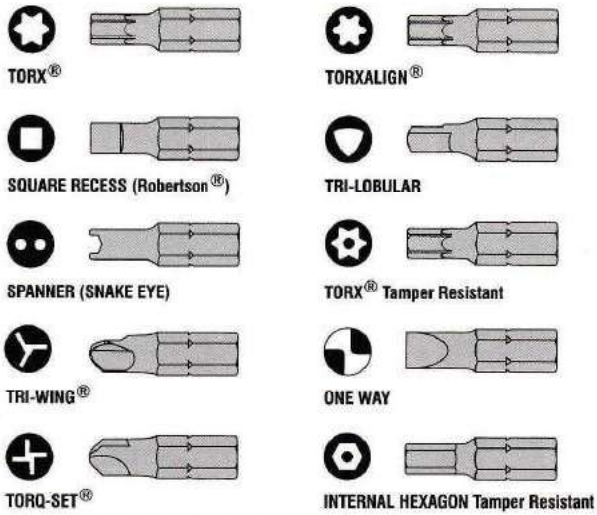
COMMON SCREW HEAD DRIVES

Standard Screw Head Drives



Tamper Resistant Screw Head Drives



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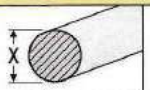
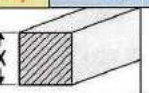
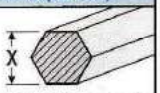
WEIGHTS OF ROUND, SQUARE & HEXAGON STEEL & BRASS BARS

Size - X		Metric (Kilograms per metre)		Inch (Pounds per foot)			
							
(mm)	(inch)	Steel	Brass	Steel	Brass	Steel	Brass
6		0.222	0.240	0.283	0.306	0.244	0.265
	1/4"	0.167	0.182	0.213	0.232	0.184	0.200
	5/16"	0.261	0.284	0.332	0.362	0.287	0.313
8		0.394	0.427	0.502	0.544	0.435	0.471
	3/8"	0.375	0.409	0.478	0.521	0.414	0.451
10		0.616	0.667	0.785	0.850	0.679	0.735
	7/16"	0.511	0.557	0.651	0.710	0.563	0.614
12		0.887	0.961	1.130	1.224	0.978	1.059
	1/2"	0.667	0.728	0.850	0.927	0.735	0.802
14		1.208	1.308	1.539	1.666	1.331	1.441
	9/16"	0.844	0.921	1.076	1.173	0.931	1.015
15		1.387	1.501	1.766	1.913	1.528	1.654
	5/8"	1.043	1.137	1.328	1.449	1.149	1.253
16		1.578	1.708	2.010	2.176	1.738	1.882
17		1.781	1.928	2.269	2.457	1.962	2.125
18		1.997	2.162	2.543	2.754	2.200	2.382
19		2.225	2.409	2.834	3.069	2.451	2.654
	3/4"	1.501	1.637	1.913	2.086	1.654	1.804
20		2.465	2.669	3.140	3.400	2.716	2.941
22		2.983	3.229	3.799	4.114	3.286	3.559
	7/8"	2.043	2.229	2.603	2.839	2.252	2.456
24		3.549	3.843	4.522	4.896	3.911	4.235
25		3.851	4.170	4.906	5.313	4.244	4.595
	1"	2.669	2.911	3.400	3.708	2.941	3.208
27		4.492	4.864	5.723	6.197	4.950	5.360
28		4.831	5.231	6.154	6.664	5.324	5.764
	1 1/8"	3.378	3.684	4.303	4.693	3.722	4.060
30		5.546	6.005	7.065	7.650	6.111	6.617
	1 1/4"	4.170	4.549	5.313	5.794	4.595	5.012
32		6.310	6.833	8.038	8.704	6.953	7.529
33		6.711	7.266	8.549	9.257	7.395	8.007
	1 3/8"	5.046	5.504	6.428	7.011	5.560	6.065
35		7.549	8.174	9.616	10.413	8.318	9.007
36		7.986	8.648	10.174	11.016	8.800	9.529
	1 1/2"	6.005	6.550	7.650	8.344	6.617	7.217
39		9.373	10.149	11.940	12.929	10.328	11.183
40		9.860	10.676	12.560	13.600	10.864	11.764
	1 5/8"	7.048	7.687	8.978	9.792	7.766	8.470
42		10.870	11.770	13.847	14.994	11.978	12.970
	1 3/4"	8.174	8.915	10.413	11.357	9.007	9.824
45		12.479	13.512	15.896	17.213	13.750	14.889
50		15.406	16.681	19.625	21.250	16.976	18.381
	2"	10.676	11.644	13.600	14.833	11.764	12.831

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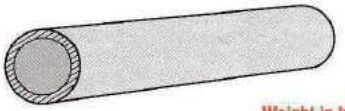
WEIGHTS OF ROUND STEEL, ALUMINIUM & BRASS PIPES



Weight in kilograms per metre

Steel Pipes

Nominal Bore (mm)	Outside Diameter (mm)	LIGHT		MEDIUM		HEAVY	
		Wall thickness (mm)	Weight (kgs/m)	Wall thickness (mm)	Weight (kgs/m)	Wall thickness (mm)	Weight (kgs/m)
15	21.3	2.00	0.962	2.65	1.22	3.25	1.45
20	26.9	2.35	1.42	2.65	1.58	3.25	1.90
25	33.7	2.65	2.04	3.25	2.46	4.05	2.99
32	42.4	2.65	2.61	3.25	3.15	4.05	3.86
40	48.3	2.90	3.27	3.25	3.61	4.05	4.43
50	60.3	2.90	4.14	3.65	5.10	4.50	6.17
65	76.1	3.55	5.84	3.65	6.53	4.50	7.92
80	88.9	3.25	6.86	4.05	8.48	4.85	10.10
100	114.3	3.65	9.97	4.50	12.10	5.40	14.50
125	139.7	4.50	14.90	4.85	16.20	5.40	17.90
150	165.1	4.50	17.80	4.85	19.20	5.40	21.20

Weight in kilograms per metre

Outside Dia. (mm)	Aluminium Pipes – Wall Thickness (mm)					Brass Pipes – Wall Thickness (mm)				
	0.5	0.8	1.0	1.5	2.0	0.5	0.75	1.0	1.5	2.0
5	0.019	0.029				0.06	0.80	0.11	0.14	
6	0.023	0.035	0.042			0.07	0.10	0.13	0.18	
7	0.28	0.042	0.051			0.09	0.13	0.16	0.22	
8	0.032	0.049	0.059	0.083		0.10	0.15	0.19	0.26	
10	0.040	0.063	0.076	0.108	0.136	0.13	0.19	0.24	0.34	
12	0.049	0.076	0.093	0.134	0.170	0.14	0.23	0.29	0.42	0.53
13	0.053	0.083	0.102	0.146	0.187			0.32	0.46	0.59
15	0.062	0.096	0.119	0.172	0.221			0.37	0.54	0.69
16	0.066	0.103	0.127	0.184	0.238			0.40	0.58	0.74
18	0.074	0.115	0.144	0.210	0.271			0.45	0.66	0.85
19	0.079	0.123	0.153	0.223	0.288			0.48	0.70	0.90
20	0.083	0.130	0.161	0.235	0.305			0.51	0.74	0.96
22	0.091	0.146	0.178	0.261	0.339			0.56	0.82	1.07
25	0.104	0.164	0.204	0.299	0.390			0.64	0.94	1.23
28	0.117	0.183	0.229	0.337	0.441			0.72	1.06	1.39
30	0.125	0.199	0.246	0.363	0.475			0.77	1.14	1.50
32		0.214	0.263	0.388	0.509			0.83	1.22	1.60

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WEIGHTS OF SHEET METAL
STEEL, ALUMINIUM, BRASS, COPPER & TIN PLATE

Sheet Steel (inch)

Gauge No.	(inch)	(mm)	Weight Lbs/ft²
0	0.3125	7.938	12.500
1	0.2812	7.144	11.250
2	0.2656	6.747	10.620
3	0.2500	6.350	10.000
4	0.2344	5.953	9.370
5	0.2187	5.556	8.750
6	0.2031	5.159	8.120
7	0.1875	4.762	7.500
8	0.1719	4.366	6.870
9	0.1562	3.969	6.250
10	0.1406	3.572	5.620
11	0.1250	3.175	5.000
12	0.1094	2.778	4.370
13	0.0937	2.381	3.750
14	0.0781	1.984	3.120
15	0.0703	1.786	2.810
16	0.0625	1.588	2.500
17	0.0562	1.429	2.250
18	0.0500	1.270	2.000
19	0.0437	1.111	1.750
20	0.0375	0.952	1.500
21	0.0344	0.873	1.375
22	0.0312	0.794	1.250
23	0.0281	0.714	1.125
24	0.0250	0.635	1.000
25	0.0219	0.556	0.875
26	0.0188	0.476	0.750
27	0.0172	0.437	0.688
28	0.0156	0.397	0.625
29	0.0141	0.357	0.563
30	0.0125	0.318	0.500
31	0.0109	0.278	0.438
32	0.0102	0.258	0.406
33	0.0094	0.238	0.375
34	0.0086	0.218	0.344
35	0.0078	0.198	0.313
36	0.0070	0.179	0.281

Sht. Steel (mm)

Thickness (mm)	Weight kgs/m²
0.18	1.44
0.20	1.60
0.22	1.76
0.24	1.92
0.28	2.24
0.32	2.56
0.38	3.04
0.44	3.52
0.50	4.00
0.56	4.48
0.63	5.04
0.75	6.00
0.88	7.04
1.00	8.00
1.13	9.04
1.25	10.00
1.38	11.04
1.50	12.00
1.75	14.00
2.00	16.00
2.25	18.00
2.50	20.00
2.75	22.00
3.00	24.00
3.50	28.00
4.00	32.00
4.50	36.00
4.75	38.00
5.00	40.00
6.00	48.00
7.00	56.00
8.00	64.00

Al, Brass, Copper Sheet (mm)

Sheet Thickness (mm)	Alu. kgs/m²	Brass kgs/m²	Copper kgs/m²
0.10		0.85	0.89
0.15		1.28	1.34
0.20	0.540	1.70	1.78
0.25	0.675	2.13	2.23
0.30	0.810	2.55	2.67
0.35	0.945	2.98	3.12
0.40	1.080	3.40	3.56
0.45		3.83	4.01
0.50	1.350	4.25	4.45
0.55		4.68	4.90
0.60	1.620	5.10	5.34
0.65		5.53	5.79
0.70		5.95	6.23
0.75		6.38	6.68
0.80	2.160	6.80	7.12
0.85		7.23	7.52
0.90		7.65	8.01
1.00	2.700	8.50	8.90
1.10		9.35	9.79
1.20	3.240	10.20	10.70
1.30		11.10	11.60
1.40		11.90	12.50
1.50	4.050	12.80	13.40
1.60		13.60	14.20
1.70		14.50	15.10
1.80	4.860	15.30	16.00
2.00	5.400	17.00	17.80
2.50	6.750	21.30	22.30
2.80	7.560	23.80	24.90
3.00	8.100	25.50	26.70
3.20	8.640	27.20	28.50
3.50	9.450	29.80	31.20

Tin Plate (mm)

Plate (mm)	Wt. kgs/m²	Plate (mm)	Wt. kgs/m²	Plate (mm)	Wt. kgs/m²
0.15	1.27	0.36	2.88	0.58	4.58
0.19	1.54	0.37	2.96	0.64	4.99
0.22	1.76	0.41	3.28	0.66	5.15
0.24	1.92	0.43	3.39	0.70	5.46
0.27	2.16	0.46	3.63	0.75	5.85
0.28	2.24	0.50	3.90	0.80	6.24
0.31	2.48	0.52	4.11	0.90	7.02
0.32	2.56	0.57	4.50	1.00	7.80

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SYMBOLS FOR ELEMENTS

Symbol	Name	Symbol	Name	Symbol	Name	Symbol	Name
Ac	Actinium	Er	Erbium	Mn	Manganese	Ru	Ruthenium
Ag	Silver	Es	Einsteinium	Mo	Molybdenum	S	Sulphur
Al	Aluminium	Eu	Europium	N	Nitrogen	Sb	Antimony
Am	Americium	F	Fluorine	Na	Sodium	Sc	Scandium
Ar	Argon	Fe	Iron	Nb	Niobium	Se	Selenium
As	Arsenic	Fm	Fermium	Nd	Neodymium	Si	Silicon
At	Astatine	Fr	Francium	Ne	Neon	Sm	Samarium
Au	Gold	Ga	Gallium	Ni	Nickel	Sn	Tin
B	Boron	Gd	Gadolinium	No	Nobelium	Sr	Strontium
Ba	Barium	Ge	Germanium	Np	Neptunium	Ta	Tantalum
Be	Beryllium	H	Hydrogen	O	Oxygen	Tb	Terbium
Bi	Bismuth	He	Helium	Os	Osmium	Tc	Technetium
Bk	Berkelium	Hf	Hafnium	P	Phosphorus	Te	Tellurium
Br	Bromine	Hg	Mercury	Pa	Protactinium	Th	Thorium
C	Carbon	Ho	Holmium	Pb	Lead	Ti	Titanium
Ca	Calcium	I	Iodine	Pd	Palladium	Tl	Thallium
Cd	Cadmium	In	Indium	Pm	Promethium	Tm	Thulium
Ce	Cerium	Ir	Iridium	Po	Polonium	U	Uranium
Cf	Californium	K	Potassium	Pr	Praseodymium	V	Vanadium
Cl	Chlorine	Kr	Krypton	Pt	Platinum	W	Tungsten
Cm	Curium	La	Lanthanum	Pu	Plutonium	Xe	Xenon
Co	Cobalt	Li	Lithium	Ra	Radium	Y	Yttrium
Cr	Chromium	Lr	Lawrencium	Rb	Rubidium	Yb	Ytterbium
Cs	Caesium	Lu	Lutetium	Re	Rhenium	Zn	Zinc
Cu	Copper	Md	Mendelevium	Rh	Rhodium	Zr	Zirconium
Dy	Dysprosium	Mg	Magnesium	Rn	Radon		

Viscosity Chart for Common Fluids

Viscosity : A measure of the resistance of a fluid to flow (usually through a specific orifice).

Thixotropic : Describes materials that are gel-like (e.g., Toothpaste) at rest but fluid when agitated.

Centipoise (cps) : It is a relative comparison between the viscosity of water and a fluid. Water is the standard by which viscosity of all fluids are measured. Water is 1 cps at 21°C (70°F).

Fluid	Approximate Viscosity (cps)
Water @ 21°C (70°F)	1
Milk	3
Kerosene / Blood	10
Ethylene Glycol / Antifreeze	15
Corn Oil	65
Motor Oil - SAE 30 / Maple Syrup	150
Motor Oil - SAE 40 / Castor Oil	250
Glycerine	1000
Corn Syrup / Honey	2000
Molasses	5000
Chocolate Syrup	10000
Ketchup	50000
Sour Cream	100000
Peanut Butter	150000
Lard	1000000
Caulking Compound	5000000
Window Putty	100000000

NOTE : The above table is intended as a general guide only. Viscosity values vary with change in temperature.

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PHYSICAL PROPERTIES OF COMMON METALS / METALLOIDS

METAL / METALLOID	Weight gms. per cm³	Weight lbs. per cu ft	Melting Point C°	Melting Point F°	Tensile Strength (approx.) tons/in.²	Brinell Hardness (approx.) HB	Conductivity Heat (Cu = 100)	Conductivity Elect. (Cu = 100)	Expansion per cent per 100°C
ALUMINIUM (Al)									
Pure Aluminium (Al 99%)	2.6	165	660	1220	-	23	55	59	0.26
Silicon Aluminium (Si 5%)	2.5	160	630	1165	-	-	47	-	-
Silicon Aluminium (Si 10%)	2.4	155	580	1075	-	-	-	-	-
BRONZE (Cu 90%, Sn 10%)	7.7	481	1040	1905	35	125	20	15	0.30
Manganese Bronze (Cu 60%, Zn 39%, Mn 1%)	8.3	522	871	1600	28	100	31	25	0.21
Phosphor Bronze (Cu 95%, Sn 4%)	8.8	550	1047	1942	25	-	21	-	-
Tobin Bronze (Cu 60%, Zn 39%, Sn 1%)	8.4	525	890	1635	26	100	29	25	0.21
ANTIMONY (Sb)	6.7	417	636	1166	-	30	4.8	4.0	0.12
BRASS									
Yellow Brass (Cu 65%, Zn 35%)	8.3	517	930	1706	45	60	29	26	
Cartridge Brass (Cu 70%, Zn.30%)	8.4	525	960	1760	43	-	31	-	-
CADMIUM (Cd)	8.6	540	321	610	4	20	23	34	0.30
CALCIUM (Ca)	1.6	101	850	1562	-	-	-	-	-
CARBON (C)	2.2	134	3550	6455	-	-	-	-	-
CHROMIUM (Cr)	6.7	419	1505	2740	-	350	-	55	0.08
COBALT (Co)	8.8	550	1483	2700	16	125	18	16	0.22
COPPER Electrolytic (Cu)	8.9	557	1082	1981	30	30	100	100	0.18
DURALUMIN (Cu 4.5%, Mn 2%, Mg, Si, Fe, bal. Al.)	2.8	174	600	1112	25	-	34	-	-
GOLD (Au)	19.2	1204	1060	1945	8	25	77	71	0.13
GUN METAL (Cu 88%, Sn 10%, Zn 2%)	8.5	534	1036	1900	9	-	13.4	-	-
IRON (Fe)									
Pure Iron	7.8	490	1535	2795	12	67	20.6	17.5	0.12
Wrought Iron	7.7	480	1510	2750	18	100	15.5	15	0.11
Cast Iron	7.2	450	1259	2300	15	180	12.2	2.9	0.11
Malleable Iron	7.4	462	1259	2300	24	110	13.3	-	0.12
LEAD (Pb)	11.3	707	326	620	1	5	8.9	8	0.30
MAGNESIUM (Mg)	1.7	108	670	1240	11	40	40	37	0.25
MANGANESE (Mn)	7.6	475	1229	2246	58	200	40	35	0.17
MOLYBDENUM (Mo)	10.4	651	2500	4532	63	147	38	35	0.06
MONEL (Ni 67%, Cu 30%, C 3%, bal. Fe, Mn, Si)	8.8	551	1315	2400	45	125	6.7	3.6	0.13
MUNTZ METAL(Cu 60%, Zn 40%)	8.4	525	900	1652	22	60	31	-	-
NICKEL (Ni)	8.9	556	1454	2650	30	85	15	18.8	0.13
PHOSPHOROUS (P)	1.82	146	44	111	-	-	-	-	-
PLATINUM (Pt)	21.3	1330	1770	3212	11	25	18	15	0.09

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PHYSICAL PROPERTIES OF COMMON METALS / METALLOIDS

METAL / METALLOID	Weight gms. per cm³	Weight lbs. per cu ft	Melting Point C°	Melting Point F°	Tensile Strength (approx.) tons/in.²	Brinell Hardness (approx.) HB	Conductivity Heat (Cu = 100)	Conductivity Elect. (Cu = 100)	Expansion per cent per 100°C
SILICON (Si)	2.4	147	1420	2588	-	-	-	1.6	0.06
SILVER (Ag)	10.5	655	960	1762	15	30	111	106	0.19
STEEL									
Low Carbon Steel	7.8	490	1483	2700	25	130	13.3	14.5	0.12
Medium Carbon Steel	7.8	490	1427	2600	34	170	13.3	14.5	0.12
High Carbon Steel	7.8	490	1371	2500	42	201	13.3	14.5	0.12
Manganese Steel (Mn 15%, C 1.5%, Si 0.2%)	7.9	495	1342	2450	45	300	-	-	0.12
Nickel Steel (Ni 3.5%, C 0.25%, Mn 0.8%)	7.8	490	1427	2600	40	217	-	-	0.12
Cast Steel	7.8	490	1427	2600	30	140	15	16	0.12
Stainless Steel	7.9	495	1398	2550	50	160	6	0.2	0.17
TIN (Sn)	7.3	458	232	450	4	6	17	13.5	0.21
TITANIUM (Ti)	4.5	281	1800	3270	32	230	-	-	0.08
TUNGSTEN (W)	19	1191	3400	6152	142	294	42	31	0.04
VANADIUM (V)	6.1	380	1750	3182	-	-	-	-	0.10
ZINC (Zn)	7.2	447	417	786	13	35	29	30	0.33

Common Chemical Compounds

Common Name	Chemical Name	Formula	Description
Baking soda	Sodium Bicarbonate	$NaHCO_3$	White powder
Black lead	Carbon or Graphite	C	Black powder
Bleaching powder	Calcium Chloro-hypo Chlorite	$CaOCl_2$	White chlorine-smelling powder
Blue stone / vitriol	Copper Sulphate	$CuSO_4.5H_2O$	Large blue crystals
Caustic Potash	Potassium Hydroxide	KOH	White deliquescent powder
Caustic Soda	Sodium Hydroxide	NaOH	White deliquescent powder
Chalk, Limestone	Calcium Carbonate	$CaCO_3$	White powder
Chile Saltpeter	Sodium Nitrate	$NaNO_3$	White crystalline substance
Condy's Crystals	Potassium Permanganate	$KMnO_4$	Small purple crystals
Epsom Salts	Magnesium Sulphate	$MgSO_4.7H_2O$	Small colourless crystals
Green Vitriol	Iron Sulphate	$FeSO_4.7H_2O$	Green crystals
Laughing Gas	Nitrous Oxide	N_2O	Colourless gas
Lime (quicklime)	Calcium Oxide	CaO	White powder
Limewater	Soln. of Calcium Hydroxide	$Ca(OH)_2$	Clear, bitter liquid
Liquid Ammonia	Ammonium Hydroxide	NH_4OH	Strongly fuming liquid
Litharge	Lead Monoxide	PbO	Orange powder
Muriatic Acid (Spirits of Salts)	Hydrochloric Acid	HCl	Strongly fuming colourless liquid
Oil of Vitriol	Sulphuric Acid	H_2SO_4	Heavy, colourless, viscous liquid
Red Lead	Triplumbic Tetroxide	Pb_3O_4	Fine, heavy red powder
Sal Ammoniac	Ammonium Chloride	NH_4Cl	White crystalline solid
Saltpeter (Nitre)	Potassium Nitrate	KNO_3	Colourless crystals
Slaked Lime	Calcium Hydroxide	$Ca(OH)_2$	White powder
Vinegar	Acetic Acid (weak)	CH_3COOH	Brown liquid
Washing Soda	Sodium Carbonate	$Na_2CO_3.10H_2O$	Large, white crystals

SHEET-METAL & WIRE GAUGES

Gauge No.	Sheet-Gauge: US Std. Sheet Gauge (inch)	Sheet-Gauge: Galvanized Sheet Gauge (inch)	Sheet-Gauge: Galvanized Sheet Gauge (mm)	Sheet-Gauge: Zinc Gauge (inch)	Sheet-Gauge: Zinc Gauge (mm)	Wire-Gauge: Steel Wire Gauge (US)* (inch)	Wire-Gauge: Steel Wire Gauge (US)* (mm)	Wire-Gauge: British Std. Wire Gauge (SWG) (inch)	Wire-Gauge: British Std. Wire Gauge (SWG) (mm)	Wire-Gauge: Music or Piano Wire Gauge (inch)	Wire-Gauge: Music or Piano Wire Gauge (mm)
1	0.281	-	-	-	-	0.283	7.19	0.300	7.62	0.010	0.25
2	0.266	-	-	-	-	0.263	6.67	0.276	7.01	0.011	0.28
3	0.250	-	-	0.006	0.15	0.244	6.19	0.252	6.40	0.012	0.30
4	0.234	-	-	0.008	0.20	0.225	5.72	0.232	5.89	0.013	0.33
5	0.219	-	-	0.010	0.25	0.207	5.26	0.212	5.38	0.014	0.36
6	0.203	-	-	0.012	0.30	0.192	4.88	0.192	4.88	0.016	0.41
7	0.187	-	-	0.014	0.36	0.177	4.50	0.176	4.47	0.018	0.46
8	0.172	0.168	4.27	0.016	0.41	0.162	4.11	0.160	4.06	0.020	0.51
9	0.156	0.153	3.89	0.018	0.46	0.148	3.77	0.144	3.66	0.022	0.56
10	0.141	0.138	3.51	0.020	0.51	0.135	3.43	0.128	3.25	0.024	0.61
11	0.125	0.123	3.13	0.024	0.61	0.121	3.06	0.116	2.95	0.026	0.66
12	0.109	0.108	2.75	0.028	0.71	0.106	2.68	0.104	2.64	0.029	0.74
13	0.094	0.093	2.37	0.032	0.81	0.092	2.32	0.092	2.34	0.031	0.79
14	0.078	0.079	1.99	0.036	0.91	0.080	2.03	0.080	2.03	0.033	0.84
15	0.070	0.071	1.80	0.040	1.02	0.072	1.83	0.072	1.83	0.035	0.89
16	0.062	0.064	1.61	0.045	1.14	0.063	1.59	0.064	1.63	0.037	0.94
17	0.056	0.058	1.46	0.050	1.27	0.054	1.37	0.056	1.42	0.039	0.99
18	0.050	0.052	1.31	0.055	1.40	0.048	1.21	0.048	1.22	0.041	1.04
19	0.044	0.046	1.16	0.060	1.52	0.041	1.04	0.040	1.02	0.043	1.09
20	0.037	0.040	1.01	0.070	1.78	0.035	0.88	0.036	0.91	0.045	1.14
21	0.034	0.037	0.93	0.080	2.03	0.032	0.81	0.032	0.81	0.047	1.19
22	0.031	0.034	0.85	0.090	2.29	0.029	0.73	0.028	0.71	0.049	1.24
23	0.028	0.031	0.78	0.100	2.54	0.026	0.66	0.024	0.61	0.051	1.30
24	0.025	0.028	0.70	0.125	3.18	0.023	0.58	0.022	0.56	0.055	1.40
25	0.022	0.025	0.63	-	-	0.020	0.52	0.020	0.51	0.059	1.50
26	0.019	0.022	0.55	-	-	0.018	0.46	0.018	0.46	0.063	1.60
27	0.017	0.020	0.51	-	-	0.017	0.44	0.016	0.42	0.067	1.70
28	0.016	0.019	0.47	-	-	0.016	0.41	0.015	0.38	0.071	1.80
29	0.014	0.017	0.44	-	-	0.015	0.38	0.014	0.35	0.075	1.91
30	0.012	0.016	0.40	-	-	0.014	0.36	0.012	0.31	0.080	2.03
31	0.011	0.014	0.36	-	-	0.013	0.34	0.012	0.29	0.085	2.16
32	0.010	0.013	0.34	-	-	0.013	0.33	0.011	0.27	0.090	2.29

NOTE: The above Gauge Nos. are provided for reference only.

Much confusion exists in the use of various gauge numbers and therefore it is best to specify the exact decimal size in either inches or mm.

* Also known as Washburn & Moen, American Steel & Wire Co. & Roebling Wire Gauges.

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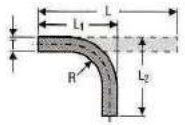
SHEET METAL BENDING ALLOWANCE

To calculate the Flat Blank Length (L) - 90° Bends



$L = L_1 + L_2 - Q$ (1 Bend)

Also $L = L_1 + L_2 + L_3 - 2Q$ (2 Bends)

Also $L = L_1 + L_2 + L_3 + L_4 - 3Q$ (3 Bends) ... Etc.

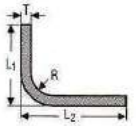
Where $Q = 0.43 \times R + 1.482 \times T$

Table for Correction Factor 'Q' (per bend)

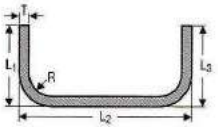
Radius 'R'	Material Thickness 'T' (mm) 0.30	0.40	0.50	0.60	0.75	1.00	1.20	1.50	2.00	2.50	3.00	3.50	4.00	5.00	6.00
0.6	0.7	0.9	1.0	1.2	1.4	1.7	2.0	2.5	3.2	3.5	4.7	5.5	6.2	7.7	9.2
1.0	0.9	1.0	1.2	1.3	1.5	1.9	2.2	2.7	3.4	4.1	4.9	5.6	6.4	7.8	9.3
1.5	1.1	1.2	1.4	1.5	1.8	2.1	2.4	2.9	3.6	4.4	5.1	5.8	6.6	8.1	9.5
2.5	1.5	1.7	1.8	2.0	2.2	2.6	2.9	3.3	4.0	4.8	5.5	6.3	7.0	8.5	10.0
4.0	2.2	2.3	2.5	2.6	2.8	3.2	3.5	3.9	4.7	5.4	6.2	6.9	7.7	9.1	10.6
6.0	3.0	3.2	3.3	3.5	3.7	4.1	4.4	4.8	5.5	6.3	7.0	7.8	8.5	10.0	11.5
10.0	4.7	4.9	5.0	5.2	5.5	5.8	6.1	6.5	7.3	8.0	8.8	9.5	10.2	11.7	13.0
15.0	6.9	7.0	7.2	7.3	7.6	8.0	8.2	8.7	9.4	10.2	10.9	11.6	12.4	13.9	15.5
20.0	9.0	9.2	9.3	9.5	9.7	10.0	10.4	10.8	11.6	12.3	13.0	13.8	14.5	16.0	17.5

Correction Factor 'Q' (mm) - per bend

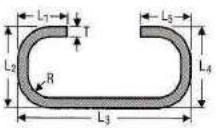
Examples



$L_1 = 25$
$L_2 = 40$
$R = 6.0$ $T = 4.0$
From Table, $Q = 8.5$
$L = L_1 + L_2 - Q$
$L = 25 + 40 - 8.5$
$L = 56.5$ Flat Blank Length



$L_1 = 25$ $L_2 = 80$
$L_3 = 25$
$R = 6.0$ $T = 3.0$
From Table, $Q = 7.0$
$L = L_1 + L_2 + L_3 - 2 \times Q$
$L = 25 + 80 + 25 - 2 \times 7$
$L = 116$ Flat Blank Length



$L_1 = 10$ $L_2 = 25$ $L_3 = 80$
$L_4 = 25$ $L_5 = 10$
$R = 4.0$ $T = 2.0$
From Table, $Q = 4.7$
$L = L_1 + L_2 + L_3 + L_4 + L_5 - 4 \times Q$
$L = 10 + 25 + 80 + 25 + 10 - 4 \times 4.7$
$L = 131.2$ Flat Blank Length

Minimum Bend Radius 'R'

Material	Material Thickness 'T' (mm) 0.30	0.40	0.50	0.60	0.75	1.00	1.20	1.50	2.00	2.50	3.00	3.50	4.00	5.00	6.00
Soft Brass Soft Copper	0.6	0.6	0.6	1.0	1.0	1.5	1.5	2.5	2.5	4.0	4.0	4.0	6.0	6.0	10.0
Aluminium Soft Steel	1.0	1.5	1.5	1.5	2.5	2.5	4.0	4.0	6.0	6.0	10.0	10.0	10.0	15.0	15.0
Cold Roll St. Stainless St.	1.5	1.5	2.5	2.5	4.0	4.0	4.0	6.0	10.0	10.0	10.0	15.0	15.0	20.0	20.0

Minimum Bend Radius 'R' (mm)

COMMON WORKSHOP METALS

The following is a compilation of metals, commonly used in day-to-day engineering applications. Its aim is to provide a basic knowledge of the metal's properties and general uses. It is always advisable to seek detailed information from the metal supplier.

Designation	Description and Uses
	Aluminium
2017A	Strong alloy offering excellent machinability for the manufacture of machine components and suitable for high speed repetition machining.
7075	This alloy offers excellent machinability combined with outstanding wear resistance & excellent polishability.
	Bronze & Brass
LG 2	**Bronze:** Leaded gunmetal Bronze, excellent machinability used in bushings, bearings, pump/valve bodies. Also available in Hollow Bar.
PB 1	**Bronze:** Phosphor Bronze very good corrosion resistance good toughness used in gears, bearings and bushes.
C38510	**Brass:** Free machining Brass used for repetition machining, high speed turning & threading.
	Bright Mild Steels
1020	Cold finished mild steel for machined parts or shafting, can be case hardened and welds readily.
1030	Medium tensile steel for shafts and medium stressed parts, can be welded if precautions are taken.
12L14	The addition of lead to this steel gives increased machinability, without marked effect on the mechanical properties. For use in automatic and semi-automatic machines for repetition parts.
	Carbon Steel
1045	A fully killed medium carbon steel, suitable for medium stressed parts in machinery & industrial tools. Can be flame or induction hardened.
1010	Soft ductile, easily welded grade, case hardenable. Main usage general fabrication.
	Carbon Hollow Bar
20MnV6	Improved carbon steel grade, universally used to reduce machining time, good weldability, can be case hardened.
	Case Hardening Steels
EN-36A	Case hardening chromium-nickel steel for applications requiring high toughness & core strength, particularly in large cross sections. Suitable for highly stressed parts, gear wheels & crankshafts.
	Cast Iron
35B	Essentially a Pearlitic grain structure Grey Cast Iron with excellent wear resistance and good machinability. Used for Hydraulic & Pneumatic piston, end caps, support bearings, etc.
	Chrome Bar
4140	A hardened and tempered alloy steel grade suitable for highly stressed mechanical parts.

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COMMON WORKSHOP METALS

Designation	Description and Uses
	Cold Work Steels
D2	Dimensionally stable, high carbon, high chrome featuring excellent toughness can be air hardened or bath nitrided. Suitable for heavy duty cutting tools, blanking and punching tools.
	Copper
C14700	A sulphur bearing copper for use in automatic & semi-automatic machines for repetition parts.
	High Speed Steels
M2	Tungsten Molybdenum High Speed Steel with excellent toughness and cutting properties. This standard grade has a wide variety of uses including drills, taps, broaches, milling tools, cold work tools, etc.
	High Tensile
4140	Suitable for applications requiring high strength & good toughness, particularly in medium to large cross-sections, medium to high stressed parts, can be flame or induction hardened or nitrided.
4340	For applications requiring high strength & toughness. Molybdenum addition prevents temper brittleness. General engineering, automotive & aircraft applications, can be flame, induction hardened or nitrided.
	Key Steel
1026, 1030	It is manufactured to close tolerances and used extensively in the manufacture of keys for shafts.
	Plastic Mould Steel
M200	Suitable for plastic moulds and holder blocks for the plastic processing, die casting industries and components for general mechanical engineering. Can be case and flame hardened, gas nitrided and chromium plated.
	Silver Steel
AISI 01	Accurately ground round bar that is used for a variety of applications such as shafts, pins, etc. Oil/water hardenable.
	Stainless Steel
303	Free cutting steel for components subjected to corrosion in mechanical and plant engineering, mass produced items such as screws, bolts and nuts. Cannot be thermally hardened.
304	General purpose austenitic stainless steel. Frequently used where welding without subsequent heat treatment is involved. Cannot be thermally hardened.
316	Marine grade offering good corrosion resistance used in food processing, chemical, fishing, hospital and brewery equipment. Cannot be thermally hardened.
316L	The same as 316 with improved weldability and machinability. Cannot be thermally hardened.

NOTE: Refer Workpiece Material Comparison Table on pages 104-107 for Equivalent National Material Designation Numbers.

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COMMON WORKPIECE MATERIAL COMPARISON TABLE

ISO	USA	Germany		U.K.	France	Japan	Sweden
				Standard			
	AISI/SAE	Mat. No.	DIN	BS	AFNOR	JIS	SS
P Steel	**PLAIN – UNALLOYED STEELS**						
	1006	1.0201	St 36		Fd 5		1160
	1010	1.1121	Ck 10 (C10E)	045 M 10	XC 10	S 10 C	1265
	1015	1.0401	Ck 15 (C15)	080 M 15	CC 12	S 15 CK	1370
	1020	1.0402	C22	050820	CC 20		1450
	1022	1.1133	GS-20Mn 5	120 M 19	20 M 5	SMnC 420	1410
	1025	1.1158	Ck 25 (C25E)	050 A 20	XC 25	S 25 C	1450
	1035	1.1183	C 35	060 A 35	CC35	S35C	1550
	1039	1.1157	40Mn4	150M36	35M5		
	1040	1.0726	35S20	212M36	35MF4		1140
	1045	1.0503	C45	080M46	CC45		1650
	1050	1.1213	Cf53	060A52	XC48TS	S50C	1674
	1055	1.0535	C55	070M55			1655
	1060	1.0601	C60	080A62	CC55		
	1095	1.1274	Ck101	060A96	XC100		1870
	1115	1.0038	Ck16	030A04			1325
	1140	1.0726	35S20	212M36	35MF4		1957
	1213	1.0715	11 SMn 30	230M07	S250	SUM22	1912
	12L13	1.0718	11 SMnPb 30		S250Pb	SUM22L	1914
	12L14	1.0737	11 SMnPb 37		S300Pb		1926
	1330	1.1170	28Mn 6	150M28	20M5	SCMn1	
	1335	1.1167	36Mn 5		40M5	Smn438(H)	2120
	A204 GrA	1.5415	15Mo 3 / 16Mo3	1501-240	15B3		2912
	A570.36	1.0038	RSt.37-2	4360 40 C	E24 2 Ne	STKM 12A	1311
	A572-60	1.8900	S380N	4360 55 E	NFA35-501		2142
	A573-81	1.0116	St.37-3	4360 40 B	E24-U		1312
	W1	1.1545	C 105 W1	BW 1A	Y105	SK 3	1880
	W210	1.1545	C 105 W1	BW 2	Y120	SUP4	2900
	LOW ALLOY STEELS						
	3135	1.5710	36NiCr6	640A35	35NC6	SNC236	
	3415	1.5732	14NiCr10		14NC11	SNC415	
	4130	1.7218	25CrMo4	1717CDS	25CD4	SCM420	2225
	4137	1.7220	34CrMo4	708A37	35CD4		2234
	4140	1.7225	42CrMo4	708M40	42CD4	SCM440	2244
	4340	1.6582	35CrNiMo6	817M40	35NCD6		2541
	5015	1.7015	15Cr3	523M15	12C3	SCr415	
	5115	1.7131	16MnCr5	527M20	16MC5		2511
	5120	1.0841	St52-3	150M19	20MC5		2172
	5132	1.7033	34Cr4	530A32	32C4	SCr430	
	5140	1.7035	41Cr4	530A40	42C4	SCr440	2245
	5155	1.7176	55Cr3	527A60	55C3	SUP9	
	6150	1.8159	50CrV4	735A50	50CV4	SUP10	2230
	8620	1.6523	21NiCrMo2-2	805M20	20NCD2	SNCM220	2506
	9255	1.0904	55Si7	250A53	55S7		2085
	9840	1.6511	36CrNiMo4	816M40	40NCD3		

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COMMON WORKPIECE MATERIAL COMPARISON TABLE

ISO	USA	Germany		U.K.	France	Japan	Sweden
				Standard			
	AISI/SAE	Mat. No.	DIN	BS	AFNOR	JIS	SS
P Steel	52100	1.3505	100Cr6	534A99	100C6	SUJ2	2258
	A182	1.7380	10CrMo9-10	1501-622	12CD9 10		2218
	A204	1.5415	15Mo3 (16Mo3)	1501-240	15D3		2912
	A573-81	1.0144	St44-2	4360-43C	E28-3	SMH400A	1412
	L1	1.7039	41CrS4	524A14			2092
	L3	1.2067	102Cr6	BL3	Y100C6		
	L6	1.2713	55NiCrMoV6		55NCDV7	SKT4	2550
	O2	1.2842	90MnCrV8	BO2	90MV8		
	S1	1.2542	45WCrV7	BS1		S1	2710
	HIGH ALLOY STEELS (TOOL & DIE STEELS)						
	440C	1.4125	X105CrMo17		Z100CD17	SUS440C	
	446	1.4749	X18CrNi28			SUH446	
	A2	1.2363	X100CrMoV51	BA2	Z100CDV5	SKD12	2260
	A353	1.5662	X8Ni9	1501.509			
	D2	1.2379	X155CrMoV121	BD2	Z160CDV12		2310
	D3	1.2080	X210Cr12	BD3	Z200C12	SKD1	
	D3	1.3343	S 6-5-2	4959BA2	Z40CSD10	SUH3	2715
	D4 (D6)	1.2436	X210CrW12	BD6	Z200CD12	SKD2	2312
	H11	1.2343	X38CrMoV51	BH11	Z38CDV5		
	H12	1.2606	X37CrMoW51	BH12	Z35CWDV5		
	H13	1.2344	X40CrMoV51	BH13	Z40CDV5	SKD61	2242
	H21	1.2581	X30WCrV93	BH21	Z30WCV9	SKD5	
	HW3	1.4718	X45GrSi93	401S45	Z45CS9	SUH1	
	M2	1.3343	S 6-5-2	BM2	Z85WDCV	SKH9	2722
	M35	1.3243	S 6-5-2-5	BM35	6-5-2-5	SKH55	2723
	M42	1.3249	S2-9-2-8	BM34			
	P3	1.2080	X210Cr12	BD3	Z200C12	SKD1	2710
	T1	1.3355	3 18 01	Bt1	Z08WCV	SKH2	
M Stainless Steel	**STAINLESS STEELS - AUSTENITIC**						
	301	1.4310	X8CrNiS18-9	301S21	Z12CN17.07	SUS301	2331
	303	1.4305	X12CrNiS18 8	303S21	Z10CNF18.09	SUS303	2346
	304	1.4350	X5CrNi18 9	304S31	Z6CN18.09	SUS304	2332
	304L	1.4306	X2CrNi19-11	304S12	Z2CrNi18.10	SCS19	2352
	304LN	1.4311	X2CrNiN18-10	304S62	Z2CN18.10	SUS304LN	2371
	308	1.4406	X10CrNi18.08	301S21	Z1NCDU25.20	SCS17	2370
	309	1.4828	X15CrNiSi20-12	309S24	Z15CNS20.12	SUH309	
	310S	1.4845	X12CrNi25-21	310S24	Z12CN25.20	SUH310	2361
	316	1.4401	X5CrNiMo17-12-2	316S16	Z6CND17.11	SUS316	2347
	316L	1.4435	X2CrNiMo18-14-3	316S13	Z2CND17.12	SCS16	2353
	316LN	1.4429	X2CrNiMoN18 13		Z2CND17.13	SUS316LN	2375
	316Ti	1.4571	X10CrNiMoTi1810	320S17	Z6NDT17.12		2350
	317L	1.4438	X2CrNiMo18-15-4	317S12	Z2CND19.15	SUS317L	2367
	318	1.4583	X10CrNiMoNb1812		Z6CNDNb1713B		
	321	1.4541	X6CrNiTi18-10	321S12	Z6CNT18.10	SU321	2337
	347	1.4550	X6CrNiNb18-10	347S17	Z6CNNb18.10	SU347	2338

COMMON WORKPIECE MATERIAL COMPARISON TABLE

ISO	Country: USA	Germany		U.K.	France	Japan	Sweden
	Standard: AISI/SAE	Mat. No.	DIN	BS	AFNOR	JIS	SS
M Stainless Steel	**STAINLESS STEELS - FERRITIC / MARTENSITIC**						
	403	1.4000	X6Cr13	403S17	Z6C13	SUS403	2301
	405	1.4724	X10CrAlSi13	403S17	Z10C13	SUS405	
	410	1.4006	X12Cr13	410S21	Z10C14	SUS410	2302
	416	1.4005	X12CrS13	416S21	Z11CF13	SUS416	2380
	430	1.4016	X6Cr17	430S15	Z8C17	SUS430	2320
	430F	1.4104	X14CrMoS17		Z10CF17	SUS430F	2383
	431	1.4057	X17CrNi16-2	431S39	Z15CNi6.02	SUS431	2321
	434	1.4113	X6CrMo17-1	434S17	Z8CD17.01	SUS434	2325
	446	1.4762	X10CrAlSi25		Z10CAS24	SUH446	2322
	CA6-NM	1.4313	X3CrNiMo13-4	425C11	Z4CND13.4M	SCS5	2385
	EV8	1.4871	X53CrMnNiN21.9	349S54	Z52CMN21.09	SUH35/36	
	HNV6	1.4747	X80CrNiSi20	443S65	Z80CSN20.02	SUH4	
K Cast Iron	**GREY CAST IRON**						
	No. 20B	0.6010	GG10		Ft10D	FC100	0110
	No. 25B	0.6015	GG15	Gd. 150	Ft15D	FC150	0115
	No. 30B	0.6020	GG20	Gd. 220	Ft20D	FC200	0120
	No. 35B	0.6025	GG25	Gd. 260	Ft25D	FC250	0125
	No. 45B	0.6030	GG30	Gd. 300	Ft30D	FC300	0130
	No. 50B	0.6035	GG35	Gd. 350	Ft35D	FC350	0135
	No. 55B	0.6040	GG40	Gd. 400	Ft40D	FC400	0140
	A436 Type 2	0.6660	GGL-NiCr202	L-NiCuCr-202	L-NC-202		0523
	MALLEABLE CAST IRON						
	40010	0.8145	GTS-45	P440/7	MN450	FCMW370	0852
	50005	0.8155	GTS-55	P510/4	MP50-5	FCMP490	0854
	A220-70003	0.8615	GTS-65-02	P570/3	MN650-3	FCMP590	0856
	A220-80002	0.8170	GTS-70-02	P690/2	MN700-2	FCMP690	0862
	NODULAR CAST IRON						
	60-40-18	0.7040	GGG 40	SNG420/12	FCS400-12	FCD400	0717.02
	80-55-06	0.7050	GGG 50	SNG500/7	FGS500-7	FCD500	0727.02
	A43D2	0.7660	GGG-NiCr202	Gd. S6	S-NC202		0776
	100.70.03	0.7070	GGG 70	SNG700/2	FGS700-2	FCD700	0737.01
N Non-Ferrous	**ALUMINIUM ALLOYS**						
	1000	3.0255	Al99-5	L31/34/36	A590 50C		
	7050	3.4345	AlZnMgCu0.5	L86	AZ4GU/9051		
	A360.2	3.2383	G-AlSi10Mg(Cu)	LM9			4253
	A413.0	3.2582	GD-AlSi12				4247
	A413.1	3.2583	G-AlSi12(Cu)	LM20			4260
	A413.2	3.2581	G-AlSi12	LM6			4261
	AZ 81	3.5812	G-MgAl8Zn1	MAG1	G-A9		
	AZ 91	3.5912	G-MgAl9Zn1	MAG7	G-A9Z1		

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COMMON WORKPIECE MATERIAL COMPARISON TABLE

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	Standard: AISI/SAE	Mat. No.	DIN	BS	AFNOR	SS
N Non-Ferrous	EZ33	3.5103	MgSE3Zn2Zr1	MAG6	G-TR3Z2	
	QE22	3.5106	G-MgAg3SE2Zr1	MAG12	G-AG22.5	
	COPPER ALLOYS					
	C 18200	2.1293	CuCrZr	CC 102	U-Cr 0.8 Zr	
	C 23000	2.0240	CuZn15	CZ 102	CuZn 15	
	C 26000	2.0265	CuZn30	CZ 106	CuZn 30	
	C 27200	2.0321	CuZn37	CZ 108	CuZn 37	
	C 63000	2.0966	CuAl10Ni5Fe4	CA 104	U-A 10 N	
	C 81500	2.1292	G-CuCrF 35	CC1-FF		
	C 83600	2.1096	G-CuSn5ZnPb	LG 2	U-E 5 Pb 5 Z 5	
	C 86200	2.0596	G-CuZn34Al2	HTB 1	U-Z 36 N 3	
	C 86500	2.0592	G-CuZn35Al1	HTB 1	U-Z- 36 N 3	
	C 90700	2.1050	G-CuSn10	CT 1		
	C 90800	2.1052	G-CuSn12	Pb 2	U-E 12 P	
	C 93200	2.1090	G-CuSn7ZnPb		U-E 7 Z 5 Pb 4	
	C 93700	2.1176	G-CuPb10Sn	LB 2	U-E 10 Pb 10	
	C 93800	2.1182	G-CuPb15Sn	LB 1	U-Pb 15 E 8	
	C 94100	2.1188	G-CuPb20Sn	LB 5	U-Pb 20	
S Heat-Resistant Super Alloys	**SUPER ALLOYS (Fe / Ni / Co / Ti - based)**					
	Hastelloy B	2.4685	G-NiMo28			
	Hastelloy C	2.4810	G-NiMo30			
	Hastelloy C4	2.4610	NiMo16Cr16Ti			
	Inconel 625	2.4856	NiCr22Mo9Nb	NA 21	NC 22 Fe DNb	
	Inconel 690	2.4642	NiCr29Fe		NC 30 Fe	
	Inconel 718	2.4668	NiCr19FeNbMo		NC 19 Fe Nb	
	Inconel X-750	2.4669	NiCr15Fe7TiAl		NC 15 TNb A	
	Inconel 751	2.4694	NiCr16Fe7TiAl			
	Incoloy 825	2.4858	NiCr21Mo	NA 16	NC 21 Fe DU	
	Monel 400	2.4360	NiCu30Fe	NA 13	NU 30	
	Monel K-500	2.4375	NiCu30Al	NA 18	NU 30 AT	
	N 08028	1.4563	X1NiCrMoCuN31274		Z1NCDU31.27	
	N 08800	1.4558	X2NiCrAlTi3220	NA 15		
	N08031	1.4562	X1NiCrMoCu32287			
	N08330	1.4864	X12NiCrSi36 16	NA 17	Z12NCS35.16	
	Nimonic 75	2.4630	NiCr20Ti	HR 5	NC 20 T	
	R 50250	3.7025	Ti 1	2 TA 1		
	R 52250	3.7225	Ti 1 Pd	TP 1		
	R 54620	3.7145	TiAl6Sn2Zr4Mo2Si			
	R 56400	3.7165	TiAl6V4	TA 10-13	T-A 6 V	
H Hardened Metals	**HARDENED METALS (WHITE / HARDENED CAST IRON)**					
	A532 A25%Cr	0.9650	G-X 260 Cr 27	Grade 3D		0466-00
	A532 A25%Cr	0.9655	G-X 300 CrMo 27 1	Grade 3E		
	Ni-Hard 1	0.9625	G-X 330 NiCr 4 2	Grade 2B		0513-00
	Ni-Hard 2	0.9620	G-X 260 NiCr 4 2	Grade 2A		0512-00

COMMON ENGINEERING PLASTICS

The following is a compilation of Common Plastics used in the Engineering Industry for the manufacture/fabrication of components. It is by no means a comprehensive list and as always, it is best to seek the advice of the manufacturer for specific applications.

Thermoplastics soften to a flowable state when heated and harden upon cooling.
Thermosetting Plastics set or harden into permanent shape and this is irreversible.

Acrylonitrile-Butadiene-Styrene ABS – Magnum ®
This is a rigid, low-cost thermoplastic which can be easily machined to a fine finish. It can be electroplated and is used in the production of mouldings, pipe fittings and products needing long life.

Acrylic – Plexiglas ® Lucite ® Perspex ® Altuglas ®
It is an optically clear transparent plastic having excellent weather resistance, high impact strength, good chemical resistance and is easily thermoformed and fabricated. It is extensively used for instrument covers & enclosures, safety shields, tanks, etc.

Bakelite
It is a hard and stiff plastic and comes with a variety of fillers such as Canvas, Paper, Cloth, etc. Being a good insulator, it is used extensively in the manufacture of base plates, handles and knobs for the electrical industry.

Chlorinated PVC CPVC – Corzan ®
This is a high heat, corrosion-resistant material with properties similar to PVC and ideally suited for components where high temperatures are necessary. CPVC pipes are preferred over PVC where mechanical strength at higher temperatures is required.

Fibreglass
It has a high strength-to-weight ratio with excellent corrosion resistant and dielectric properties. Used extensively in boat building and tank manufacturing.

High Density Polyethylene HDPE – Polystone HD 300 ®
It is an economical, high-impact, lightweight thermoplastic with excellent chemical resistance and high tensile strength. It exhibits excellent resilience, stress, crack and abrasion resistance. It is easily machined and requires welded or mechanical assembly.

High Molecular Weight Polyethylene HMWPE – Polystone HM 500 ®
It has high rigidity and creep resistance, ideal to use in the food industry in the manufacture of cutting boards, underlays in food preparation and machine parts.

Phenolics – Tufnol ®
It has minimum thermal expansion, high compressive strength and excellent and abrasion resistance with a low coefficient of friction. It is used extensively for electrical insulators, bushes, busbar supports and cable clamps.

Polyacetal (Acetal) POM – Delrin ® Ertacetal C ®
It has high hardness, stiffness, excellent creep resistance & dimensional stability with a low coefficient of friction. Used extensively for the manufacture of precision gears and bearings, electrical insulators, and parts which operate in water between 60° and 90°C.

Polyamide (Nylon) PA – Nylatron ® Nylube ® Kevlon ® Stanyl 46 ®
It has high damping properties, good dimensional stability, self-lubricating, high wear resistance with excellent bearing & sliding properties. Used extensively to manufacture gears, bearings, rollers, wear pads and guide wheels. There are many speciality grades available in this range.

COMMON ENGINEERING PLASTICS

Polycarbonate PC – Lexan ® Makrolon ® Hyzod ®
It is a virtually unbreakable transparent thermoplastic used extensively in safety and security-related applications. Common uses include safety shields, enclosures, safety spectacles, machine guards and bullet-resistant applications. It is easily glued.

Polyethylene PE
It has excellent abrasion resistance, low coefficient of friction, very high surface release, chemical resistance, impact resistance and damping properties. It is used extensively in the food industry where direct contact with foodstuffs is necessary.

Polyether-Ether-Ketone PEEK – Victrex ® Ketron ®
It has excellent wear, toughness and impact strength and good dimensional stability. Addition of graphite and carbon fibres results in a bearing grade with low friction and long wear applications. Used in the manufacture of gears, bearings, valves and pumps.

Polyethylene Terephthalate PET
This is a dimensionally stable thermoplastic with excellent machining characteristics and used in place of Acetal when machining is the main criteria.

Polypropylene PP – Simona ® Gehr ® Polystone PP ®
It is an economical, lightweight thermoplastic that offers high corrosion, abrasion and impact resistance. It also exhibits high tensile strength and stiffness at elevated temperatures and is superior to HDPE. It is easily machined and welded.

Polysulphone PSU – Ultrason S ® Udel ®
It offers excellent radiation stability and good chemical resistance, often replacing polycarbonate whenever higher temperature (in excess of 150°C) is required. Used commonly in the food processing industry in milk machine pumps, valves and filtration plates and for medical components subject to sterilisation.

Polytetrafluoroethylene PTFE – Teflon ® Tetron ®
It has a combination of chemical, electrical, mechanical and thermal properties and the lowest coefficient of friction unmatched in other plastics. It is the most chemically inert of any material. Being non-stick, it is used extensively in the coating of cooking utensils, seals, seats, packings, slide bearings and electrical and thermal insulators.

Polyurethane PU
It has excellent impact and abrasion resistance and resists sunlight and weathering

Polyvinyl Chloride PVC – Simona ® Gehr ® Darvic ® Cobex ®
A high corrosion-resistant plastic ideally suited where chemical resistance to acids, alkalies, alcohols and halogens is necessary. It has a high strength to weight ratio and is easily fabricated either by welding or gluing. **Unplasticised PVC (uPVC)** is used extensively for pipe & pipe fittings because of its excellent stiffness properties.

Polyvinylidene Fluoride PVDF – Solef ® Kynar ® Hylar ®
It is a high performing thermoplastic combining great mechanical strength and abrasion resistance. It is highly resistant to most environmental conditions and corrosive materials.

Ultra High Molecular Weight PE UHMWPE – Saxin New-Light ® Simona ®
It is extremely high abrasion resistant when compared to other thermoplastics. It also has exceptional impact resistance even at cryogenic temperatures; it is chemical resistant and self-lubricating.

COMMON ENGINEERING ADHESIVES

The following is a compilation of Common Adhesives used in the Engineering Industry for bonding components. It is by no means a comprehensive list and as always, it is best to seek the advice of the manufacturer for specific applications.

Acrylic / Acrylate : This adhesive is a chemically activated two component structural adhesive and comes in a wide variety of types, e.g., General purpose, High peel and Shock resistant, for use on metal, ceramics and plastic materials such as ABS, Polystyrene and Polycarbonate. Acrylic adhesives are known for their excellent environmental resistance and fast setting time when compared to other resin systems.

Cyanoacrylate (Super Glue) / Anaerobic : Comes in a variety of viscosities for gap filling between substrates. May be used with accelerator/primer. Hardening takes place in a few seconds and for this reason are frequently used in the assembly of small parts. They bond most types of rubber extremely well and have high strength, excellent adhesion to a wide variety of substrates, especially plastics.

Epoxy : Usually come as an Adhesive/Hardener two part compound with a variety of setting times. Epoxy adhesives are widely used for their toughness and resistance to chemical and environmental damage.

Hot Melt : These are solvent-free thermoplastics that melt above 180°F and then rapidly set upon cooling. They can be repeatedly softened by heat which allows parts to be removed, repositioned or replaced during assembly. A hot melt glue gun is used for dispensing the adhesive.

Light Cure : This adhesive cures in seconds on exposure to UV light sources and is specially suitable for bonding glass to glass and glass to metal.

Phenolic, Melamine & Formaldehyde Resins : These are thermosetting adhesives that offer strong bonds and good resistance to high temperatures.

Polysulphides : It is basically a caulking type adhesive that's primarily used for ceiling seams. When cured, it is completely waterproof.

Polyurethane : These are mainly available as two part systems. Their flexibility is greater than most other epoxies and exhibit high peel and cohesive strength.

Polyvinyl Acetate (PVA) : It is intended primarily for wood and paper bonding and is transparent when dry.

Polyvinyl Chloride (PVC) : It is intended primarily for bonding glass, china, porcelain and other ceramic materials. Also used for metal, marble and hard plastics but not recommended for wood.

Pressure Sensitive (Contact Adhesive) : These adhesives adhere to most surfaces with very light pressure. They are available in solvent and latex or water-based forms. Both surfaces of the substrate need to be coated with the adhesive and allowed to dry prior to assembly.

Thread Locking & Sealing : Basically an anaerobic sealant intended to produce a waterproof/airtight seal between two mating parts and comes in a variety of strengths ranging from permanent to easily dismantleable.

Silicones : Silicone adhesives have a high degree of flexibility and very high temperature resistance (upto 600°F) when compared to other adhesives but lack the strength of other epoxy or acrylic resins. Room temperature vulcanising (RTV) forms cure through reaction with moisture in the air. It is used extensively in the window glass industry because of its high flexibility, excellent adhesion and high working temperature. This adhesive comes packed mainly in cartridges and is dispensed using a caulking gun.

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COMMON ENGINEERING ADHESIVES

Surface Preparation Prior to Bonding

In general, three steps are necessary for cleaning any surface prior to bonding.

1. **De-greasing :**
   Metals - A good quality commercial de-greaser is recommended.
   Plastics - A suitable solvent such as Acetone / Methyl Ethyl Ketone is recommended.
2. **Chemical Etching :** A suitable acid-based commercial etcher is recommended.
   Mechanical Abrading : A Medium grit blasting (sand blasting) using Aluminum Oxide, Silicon Carbide or Garnet grit is recommended.
3. **Final De-greasing :** A good quality commercial de-greaser is recommended.

In all cases, parts should be bonded as soon as possible after surface preparation.

Aluminum – De-grease with solvent and dry, clean the surface with suitable Chromic acid solution, rinse thoroughly with clear running water and dry well. Then bond immediately.

Cast Iron – De-grease, Grit blast and final de-grease.

Copper & its Alloy – Immerse in recommended acid, rinse in clear running water, dry and then bond.

Galvanized / Zinc Finished Metals – De-grease, abrade, de-grease, dry & then bond.

Glass – For normal bonding applications, de-greasing alone is sufficient. However, for optimum strength, the section to be bonded should be grit blasted with very fine Silicon Carbide grit and then bonded.

Magnesium & its Alloys – De-grease, immerse in suitable Sodium Hydroxide solution. Rinse in cold water and then immerse in suitable Chromic acid/ Chromic Nitrate solution. Rinse again and then immerse again in suitable Hydrofluoric solution. Rinse again. Dry in hot air blast and bond immediately.

Stainless Steel – De-grease, etch, rinse, followed by immersion in suitable Hydrofluoric/ Nitric acid solution. Finally rinse and hot air dry.

Steel – De-grease, medium grit blast, final de-grease and dry.

Teflon – Special etching solutions are recommended prior to bonding.

Phenolic, Polyester, Polyurethane Resins – De-grease, abrade and de-grease again.

Rubber – Surface etching/abrading is recommended followed by thorough rinsing.

Tin – De-grease, abrade and de-grease again.

Common Solvents / Cleaners

Acetone – Used mainly to clean and remove epoxy resins, adhesives, contact cement and ink stains. Dissolves/softens many plastics.

Cyanoacrylate (Super Glue) Adhesive Remover – Used in the removal of unwanted super glue from metal, plastic and rubber surfaces. To disassemble bonded part, soak in solution for extended period of time.

Lacquer Thinner – Used mainly for thinning lacquers (paints) and also used extensively as a general cleaner/de-greaser. It is highly flammable & dissolves/softens many plastics.

Methylene Chloride – When mixed with xylene, makes a strong solvent for cleaning ink, gum, latex, oil and wax. Dissolves/softens some plastics.

Solvent Alcohol (Methyl Alcohol) – An excellent cleaner for electrical & electronic parts.

Denatured Alcohol (Ethyl Alcohol) – Excellent for cleaning glass and metal.

Turpentine – Mainly used as a thinner/cleaner for oil-based (enamel) paints & varnishes.

Kerosene – Used extensively as a general purpose cleaner/degreaser.

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STANDARD GRINDING WHEELS MARKINGS

Standard Wheel Markings: For clarity as well as to avoid mistakes in wheel selection, a standard designation of wheel specification was developed and was inscribed by ISO in 1965. A typical wheel marking includes the following information:

38A	46	J	8	V	S
Abrasive	Grit	Grade	Structure	Bond Type	Mfr.'s Symbol

Abrasive

Symbol	Characteristics
A	Regular aluminium oxide, hard & tough.
10A, 11A	Premium quality of aluminium oxide.
WA, 38A	White aluminium oxide, hard & brittle
FA, 57A, 89A	Semi-friable, aluminium oxide.
32A, 90A	Strong, sharp mono-crystalline aluminium oxide.
PA, 41A, 88A	Pink aluminium oxide.
RA, 25A, 46A	Ruby aluminium oxide, hard and less brittle than PA.
PSA	Special pink abrasive.
FSA	Special Semi-friable aluminium oxide.
AZ	A modified, high zirconia aluminium oxide.
C, 37C, BC	Black silicon carbide.
GC, 39C	Green silicon carbide.
AC	Blend of A and C

Grit

Coarse	Medium	Fine	Very Fine	Ultra Fine
10 12 14	30 36 46	70 80 90 100	240 280 320 400	1000 1200 1500 2000
16 20 24	54 60	120 150 180 220	500 600 700 800	2500 3000 4000 6000

Grade : Indicates the relative strength of the bond which holds the abrasive grains in place.

Very Soft	Soft	Medium	Hard	Very Hard
D.E.F.G.	H.I.J.K.	L.M.N.O.	P.Q.R.S.	T.U.V.W.X.Y.Z.

Structure (Sometimes omitted in wheel markings)

Symbol No.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Abrasive Ratio %	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34

Bond Type

V - Vitrified (Ceramic) : Most common bond used extensively for precision grinding. The porosity & strength of the vitrified bond allows high stock removal & its rigidity helps to maintain consistent precision. Not affect ed by water, acid, oils or ordinary temperature variations.

B - Resinoid (Organic) : Used for high-speed wheels in fabrication shops & foundries. This bond is excellent for rapid stock removal and heavy work. Resinoid bond is used in most cutting-off and snagging wheels. However, it tends to deteriorate over time and, thus has a limited shelf life.

R - Rubber : Used for centreless grinding feed wheels and for precision ball race grinding wheels. Useful where finish is critical and where burrs and burn need to be held to a minimum.

E - Shellac : Used for roll grinding and other cylindrical grinding operations where fast stock removal and finish are important.

S - Silicate : Used for wheels where heat generated in grinding must be kept to a minimum.

O - Magnesite : Used for wheels designed for spring grinding and thin work pieces.

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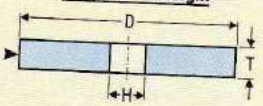
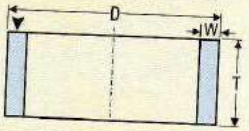
STANDARD GRINDING WHEEL SHAPES

▼ Primary Grinding Face ▽ Secondary Grinding Face

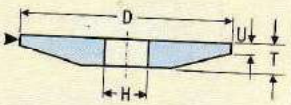
Shape 1 - Straight



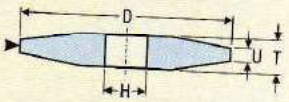
Shape 2 - Cylindrical



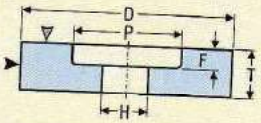
Shape 3 - Tapered One Side



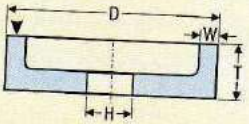
Shape 4 - Tapered Two Side



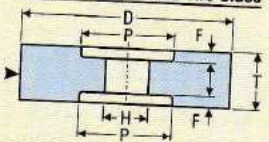
Shape 5 - Recessed One Side



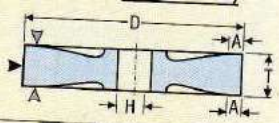
Shape 6 - Straight Cup



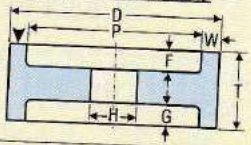
Shape 7 - Recessed Two Sides



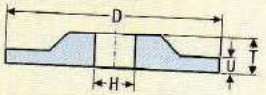
Shape 8 - Relieved Both Sides (Standard Hub)



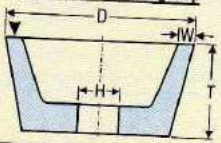
Shape 9 - Double Cup



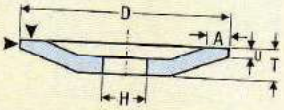
Shape 10 - Raised Dovetail



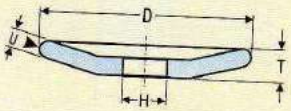
Shape 11 - Flaring Cup



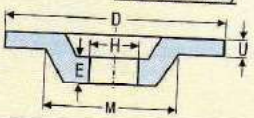
Shape 12 - Dish Type



Shape 13 - Saucer



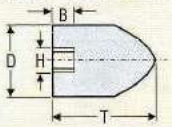
Shape 14 - Depressed Center (For Valve Seat)



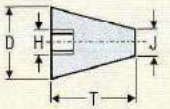
STANDARD GRINDING WHEEL SHAPES

▼ Primary Grinding Face ▽ Secondary Grinding Face

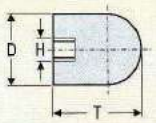
Shape 16 - Cone Curved Side



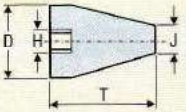
Shape 17 - Cone Square Tip



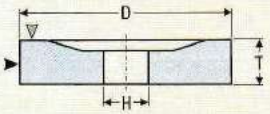
Shape 18 - Plug, Round End



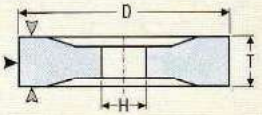
Shape 19 - Plug, Conical End



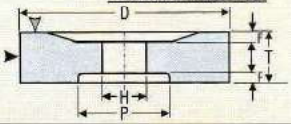
Shape 20 - Relieved One Side



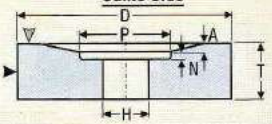
Shape 21 - Relieved Both Sides



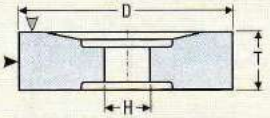
Shape 22 - Relieved One Side Recessed Other Side



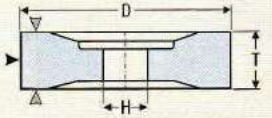
Shape 23 - Relieved & Recessed Same Side



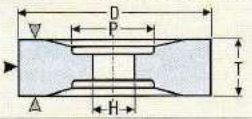
Shape 24 - Relieved One Side Recessed Both Sides



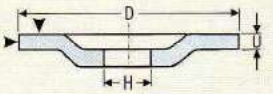
Shape 25 - Relieved Both Sides Recessed One Side



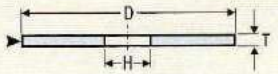
Shape 26 - Relieved Both Sides Recessed Both Sides



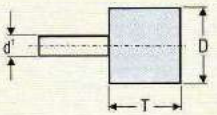
Shape 27 - Depressed Centre (Reinforced)



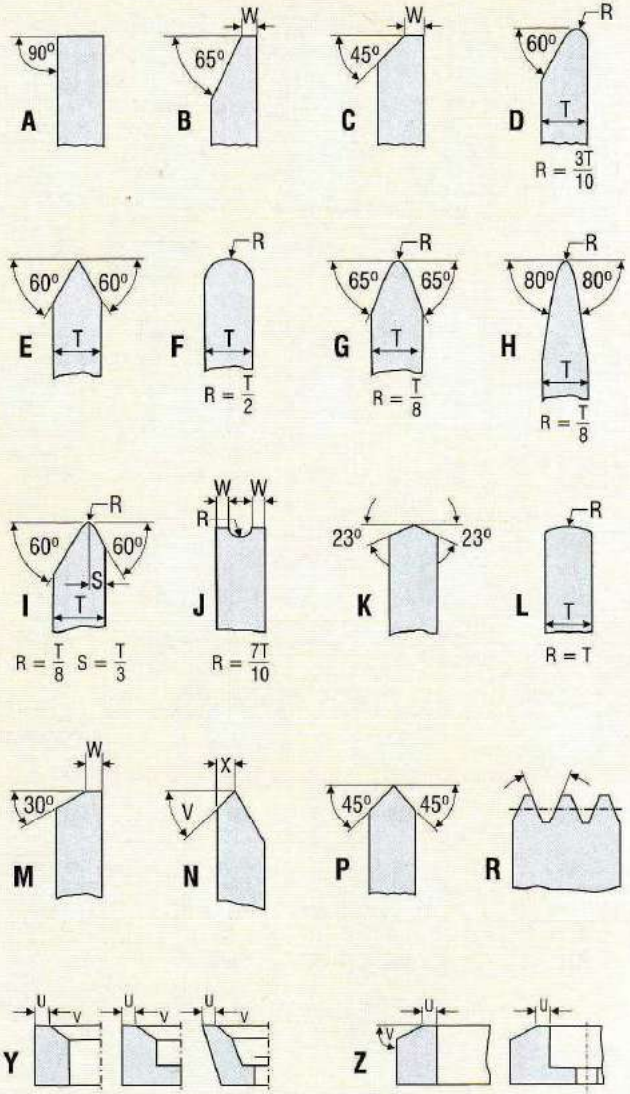
Shape 30 - Cut-Off



Shape 40 - Mounted

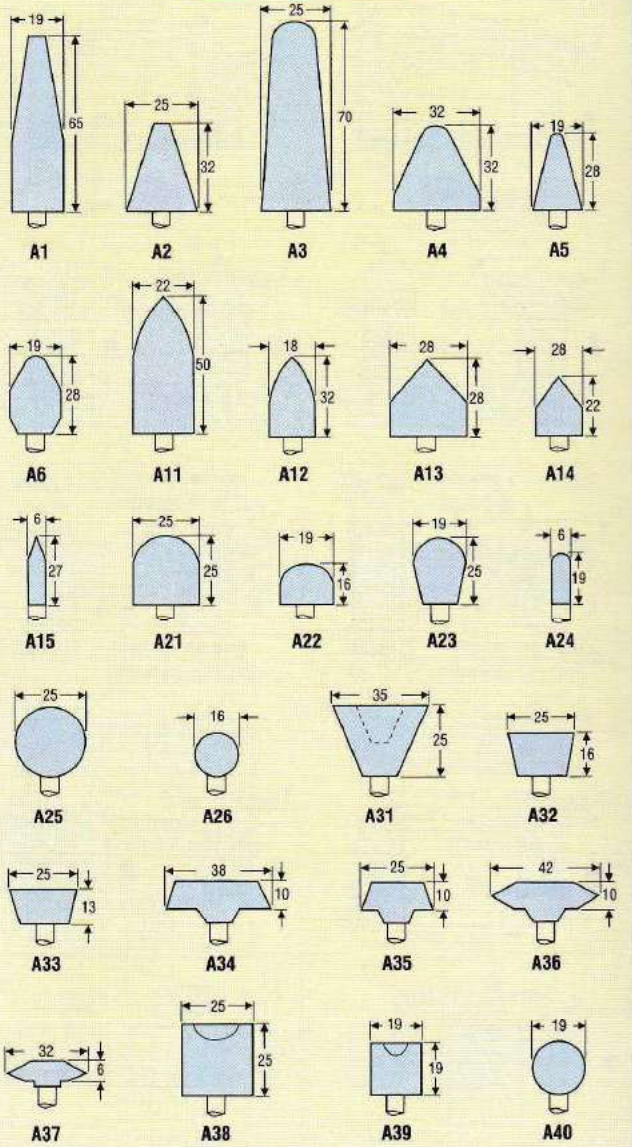


STANDARD GRINDING WHEEL FACES



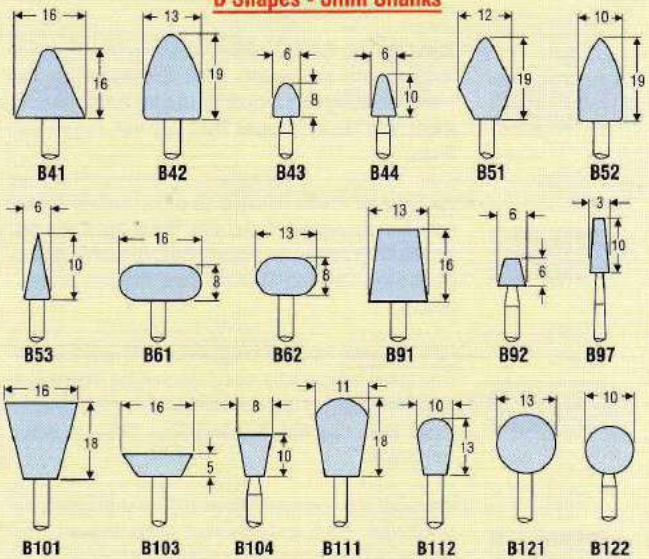
STANDARD MOUNTED WHEEL POINTS SHAPES & DIMENSIONS

A Shapes - 6 mm Shanks

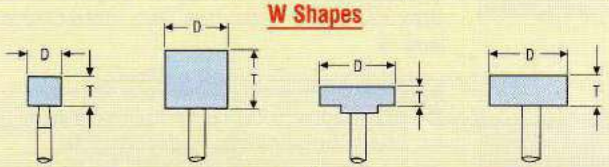


STANDARD MOUNTED WHEEL POINTS SHAPES & DIMENSIONS

B Shapes - 3mm Shanks



W Shapes



Shape No.	D (mm)	T (mm)	Shank Diameter (mm)
W144	3	6	3
W153	5	10	
W154	5	13	
W160	6	6	
W162	6	10	
W163	6	13	
W164	6	19	
W175	10	10	
W177	10	19	
W178	10	25	
W185	13	13	
W186	13	19	
W187	13	25	

Shape No.	D (mm)	T (mm)	Shank Diameter (mm)
W195	16	19	6
W196	16	25	
W204	19	19	
W205	19	25	
W216	25	6	
W217	25	10	
W220	25	25	
W225	32	6	
W226	32	10	
W230	32	32	
W235	38	6	
W236	38	13	
W242	50	25	

NOTE: Mounted wheels are designed primarily for off-hand grinding applications and are generally made of Aluminum Oxide or Silicon Carbide abrasive in vitrified or resinoid bond. They come in a selection of coarse, medium or fine grit.

TUNGSTEN CARBIDE ROTARY BURRS

Basic Cuts

Standard Cut: General purpose design producing good metal removal and smooth finish. Excellent where the metal is relatively hard and will not clog the flutes.
Uses: Steel Alloys, Stainless Steel, Cast Iron, Copper and Brass.

Double Cut: Produces rapid stock removal in harder materials with minimum tool chatter. This design eliminates loading of the flutes & the production of sharp sliver chips.
Uses: Steel, Cast Iron, Stainless Steel, Titanium, Brass & Copper.

Chip Breaker: Provides the operator with excellent tool control and reduced sliver size chips. Surface finish will be slightly reduced due to the chip breaker pattern.
Uses: Steel, Cast Iron, Stainless Steel, Titanium, Brass and Copper.

Diamond Cut: Extremely good tool control producing powder-like chips and increased metal removal. The surface finish, however, will be slightly reduced.
Uses: Heat-treated Steels, Fibre Glass, Nickel-Chrome Steel, etc.

Aluminium Cut: Recommended for use on soft materials. The flute design produces rapid metal removal on non-ferrous metals and eliminates clogging of the flutes.
Uses: Aluminium, Plastics, Soft Copper, Rubber & Zinc Die Castings.

Standard Shapes

Cylinder Shape - with/without End Cut

Cylinder Shape - Radius End

Tree Shape - Radius End

Tree Shape - Pointed End

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TUNGSTEN CARBIDE ROTARY BURRS

Oval Shape

Ball Shape

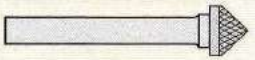
14° Taper Shape - Radius End

Flame Shape

Cone Shape - ∠ 14° to 28°

Inverted Cone Shape - ∠ 10° to 30°

60° Cone Shape



90° Cone Shape

Operating Speed Recommendations (RPM)

Size (Head Diameter) (mm)	(inch)	Standard Cut	Double Cut / Chipbreaker	Diamond Cut	Aluminium Cut
1.5	1/16"	45,000	50,000	60,000	-
3	1/8"	32,000	35,000	42,000	-
5	3/16"	22,000	25,000	30,000	-
6	1/4"	20,000	22,000	25,000	46,000
10	3/8"	16,000	18,000	22,000	31,000
12	1/2"	15,000	16,000	19,000	23,000
16	5/8"	14,000	15,000	18,000	15,000
20	3/4"	13,000	14,000	16,000	12,000
25	1"	10,000	12,000	14,000	8,000

NOTE: The above speeds are recommended for Burrs with Standard Shank Lengths and should be reduced significantly for Burrs with extra long shanks.

The recommended speeds are intended as a General Guide only for Steels, Alloys and Non-ferrous metals.

The Speed for Stainless Steel should be increased by approximately 25%.

Important Note : Because of the high speeds involved, it is most important that approved safety glasses be worn at all times to avoid slivers from entering the eye.

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SURFACE COATINGS

Physical Vapour Deposition (PVD)
A low-temperature process that produces very tough coatings with high lubricity for use on gummy materials, high temperature alloys, low-carbon steels, and stainless steels at low to medium speeds.

Chemical Vapour Deposition (CVD)
A high-temperature process that produces highly crater resistant coatings with a good balance of toughness and wear resistance for use on a broad range of carbon and stainless steels at medium to high speeds.

Medium Temperature Chemical Vapour Deposition (MTCVD)
This is a medium-temperature process that produces tougher, slightly less wear-resistant coatings than the traditional CVD process and is recommended for use on gummy materials, ductile irons and high temperature alloys at medium speeds.

Blackening
Blackening is a finishing operation that chemically coats the surface of ferrous metals. Besides enhancing the appearance of the components, the black deposit holds a sealant, usually oil, into the pores of the black oxide coating, where it is held in close contact with the metal and prevents corrosion. There are three types of blackening:

1. **Copper/Selenium Blackening** - This process uses a room temperature acid bath to form a black copper selenium coating in approximately 1-3 minutes.
2. **Caustic Black Oxiding** - A caustic soda bath operating at about 140°C produces a black coating on the surface of the ferrous metal.
3. **Black Dyed Oxylate Coating** - It provides a high quality black corrosion resistant coating on ferrous metals without using heated chemicals. A grey ferrous oxylate coating is applied to the steel and it is then dyed black. This process operates at room temperature.

The performance of any black coating is gauged by its porosity and ability to absorb a subsequent coating of oil which acts as a rust barrier. It is extensively used to coat Tungsten Carbide tool holders, Boring bars and Milling cutters to enhance appearance of the tool.

Blue Finish
Blue Finish is a thin layer of Iron Oxide produced by a carefully controlled steam tempering process. This produces a very thin oxide layer which acts as a lubricant and anti-weld surface. It also increases resistance to corrosion and enables the surface of a tool to absorb lubricant in machining operations.

Bronze Finish
The Bronze Finish is a thin oxide layer formed on the tool surface and is applied on High Speed Cobalt Steels.

Chromium Carbide (CrC)
A super hard coating > HRC 80 is applied to the surface using PVD coating process. The hardness of the coating is the same as TiN but with an oxidation resistance that is 20 to 30% higher. Recommended for machining Titanium and Aluminium alloys.

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SURFACE COATINGS

Chromium Nitride (CrN)
This is a PVD coating and is particularly suitable in non-ferrous applications where titanium based coatings are not successful. It has a surface hardness of approximately 80 Rc and has good corrosion and oxidation resistance. It is mainly used for machining Copper, Die-casting, Brass forgings.

Diamond Coating
It is an amorphous diamond coating with extremely low coefficient of friction and high hardness. This coating is specially recommended for tapping Aluminium alloys with high Silicon content.

Hard-Chromium Plating
The tool is plated with Chromium to improve wear characteristics and reduce sliding resistance and cutting forces. It is especially suitable when tapping Structural grade steels, Copper, Brass, etc.

Nitriding
Nitriding is a process which is used to increase the hardness and wear resistance of the surface of a tool. It is particularly suitable for taps that are used on abrasive materials such as castings, bakelite, etc.

Steam Tempering
Steam tempering reduces sliding resistance, thus preventing cold welding, which occurs for example during the machining of Steels that have a low carbon content. Steam tempered tools are mainly used for machining of ferrous materials.

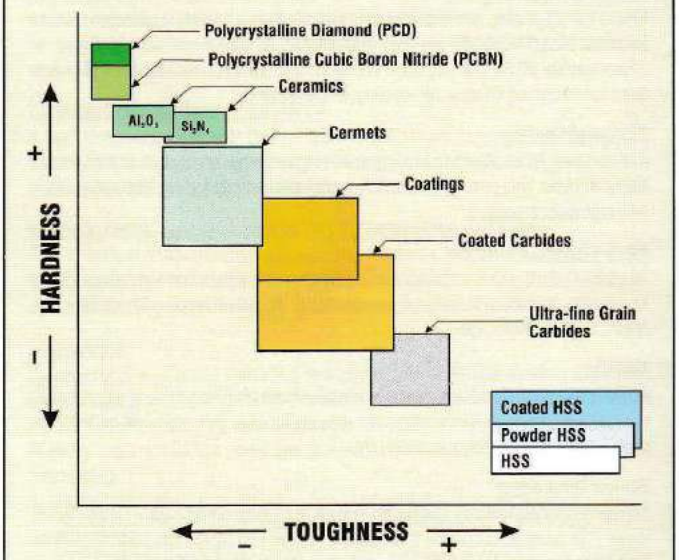
Titanium Aluminium Nitride (TiAlN)
This coating is applied by the PVD process and has a higher hardness than TiN and TiCN. A very thin film of Al_2O_3 (Aluminium Oxide) is formed on the surface of the TiAlN which greatly increases the service life of the tool which can withstand higher temperatures especially when machining Cast iron and tough steels.

Titanium Carbonitride – TiCNite (TiCN)
TiCNite coated tools have a very high surface hardness of approximately 90 Rc. TiCN is harder than other coating materials, hence cutting speeds similar to carbide tools can be achieved with the toughness of high-speed-steel. This coating is recommended for use in all steels, cast iron and aluminium.

Titanium Nitride – TiNite (TiN)
A gold coloured film of Titanium Nitride with a hardness of approximately 85 Rc is deposited on the tool which extends tool life by reducing friction and enables the tool to be operated at higher speeds and feeds. It is suitable for machining iron-based materials, die-casting and plastic mould tooling. Other applications include wear parts, medical and dental instruments, slitting knives, plastic die moulds, carbide tools, and high performance forming tools.

Zirconium Nitride (ZrN)
It is a ceramic coating applied by the PVD process. Especially recommended for tapping Aluminium and Aluminium alloys.

RELATIVE POSITION OF VARIOUS CUTTING TOOL MATERIALS



Applications and Productivity Advantages

Material	Principal Characteristics	Typical Applications	Cost/Productivity Advantages
HSS	Tougher Cutting material than carbide.	Screw-machine and other low-speed operations, interrupted cuts, low-horsepower machining.	Priced lower than carbide; gives longer tool life, better surface finish.
TiC/TiN Cermet	Excellent resistance to wear, shock and heat.	Finishing operations on irons, steels, stainless steels and aluminium alloys.	Up to 20 times the tool life of conventional Carbide grades.
Ceramics	High hardness.	Steel mill-roll resurfacing, finishing operations on cast irons & steels.	Better finishes at higher machining rates.
Silicon Nitride	High hardness *plus* high fracture toughness and thermal shock resistance.	Roughing and finishing operations on cast irons.	Machining speeds up to 1500 m/min and beyond.
Cubic Boron Nitride	Exceptional hardness.	Hardened work materials in 45-70 Rockwell C range.	Provides many times the edge life of carbide ... eliminates need for costly alternative grinding operations.
Polycrystalline-Diamond-Tipped Carbide Inserts	Hardness of diamond ... *plus* carbide toughness.	Roughing to finishing operations on aluminium and other soft or abrasive non-ferrous or non-metallic materials.	Better than 30 times the tool life of carbide, even on high silicon aluminium.
Solid Polycrystalline-Diamond Inserts	Hardness of diamond ... *and* indexable.	Roughing & finishing operations on abrasive non-ferrous or non-metallic materials.	Many times the tool life of carbide.

TUNGSTEN CARBIDE GRADES

APPLICATION

ISO Class	Grade	Materials	Cutting Methods	Application	Composition	Features
P	P10	Steel Cast steel	Turning Milling Threading	General Cutting at Medium-high speed	WC + Co + TiC + TaC	TiC & TaC is added for improving heat and crater resistance.
	P20					
	P30			Low-medium Speed Roughing		
M	M10	Stainless Steel	Turning Milling	Medium speed	WC + Co + TiC + TaC	Less TiC & TaC is added. Better wear and shock resistance, but less heat and crater resistance than P grades.
	M20					
	M40			Heavy cutting at Low speed		
K	K10	Cast iron Hardened steel Non-ferrous metal Non-Metallics	Turning Milling Reaming	Finishing	WC + Co	No TiC or TaC. Excellent mechanical wear resistance and shock resistance.
	K20			Medium speed		
	K30			Low-medium speed		

PHYSICAL & MECHANICAL PROPERTIES

ISO Class	Grade	Hardness (HRA)	Transverse Rupture Strength (kg/mm^2)	Young's Modulus ($10kg^2/mm^2$)	Thermal conductivity (cal/cm . sec . K)	Compressive strength (kg/mm^2)	Thermal expansion coefficient ($10^{-6}/°C$)
P	P10	92.7	> 200	53	0.07	460	6.5
	P20	92.5	> 210	54	0.08	480	6.0
	P30	91.2	> 250	57	0.10	480	5.5
M	M10	92.8	> 200	58	0.12	500	5.5
	M20	92.1	> 250	57	0.15	490	5.5
	M40	89.1	> 330	54	0.14	440	5.5
K	K10	92.7	> 240	64	0.19	620	4.7
	K20	92.1	> 260	62	0.19	530	5.0
	K30	91.5	> 250	62	0.19	530	5.0

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TUNGSTEN CARBIDE GRADES COMPARISON TABLE

UNCOATED GRADES

ISO Classification		ISCAR	KENNAMETAL	MITSUBISHI	NEWCOMER	R T W	SANDVIK	SECO	SUMITOMO	TAEGUTEC	TUNGALOY	VALENITE
P	P01	IC20N			N80	CY31	S1P	F1F		CT320	NS530	VC8
	P10	IC70	K2885 K45	STi10T	N70 N72	CY14 CY7	S1P	S10M 350	ST10P	P10	TX10S TX10D	VC7 VC165
	P20	IC50M IC70	K125M K29 K45	UTi20T STi20T	N60	CY16 CY7 CY30M	SMA S4 S10T	S10M 370 S25M	ST20E	P20	TX20 TX25 UX25	VC7
	P30	IC54 IC50M	KMF K21 K420	UTi20T STi20T	N55 N52	CY30M	SM30 S4	S25M 370 S35M	A30N A30 ST30E	P30	TX30 UX30 TU20	VC5 VC35M
	P40	IC54	PVA GX K21	UTi40T	N51	CY55	S6 R4 SMA	S60M S25M	ST40E	P40	TX40 TX30 TU40	VC111
M	M10	IC70	K313 K68 KM1	UTi10T UTi20T	NP32 NT56 N60	CQ23	H10A S1P	HX 890 S10M	U10E EH10	M10	TU10 TU20	VC29 VC2
	M20	IC50M	KMF K8735 K6 K21	UTi20T	N55 N52	CY30M CQ22	H13A	883 HX H15 S25M	U2 EH20 A30	M20	TU20 UX30	VC29 VC2 VC901 VC28
	M30	IC28 IC54	PVA K420 K2885 K2S	UTi20T UTi40T	NP45 N51 N016	CY55 CQ22	H10F	S60M 370 S25M HX	A30N A30 EH20	M30	UX30 TU40	VC111 VC105
K	K01	IC07	K68 K313	HTi05T RT9005	N40	CQ23 CQ28	H1P	999	H2 H1	UF1	TH03	VC3 VC29
	K10	IC10 IC20	K8735 K313 K68 K6	HTi10T RT9010	NP32 N30 N21	CQ23 CQ28	H10A HM H10 H1P	890 H15 HX	EH10 EN510 H1	K10	G1F H10T TH10	VC29 VC3
	K20	IC20 IC10	KMF K6 K1	RT9010 HTi20T	NP45 N406 N22	CQ22	H13A	890 HX 883	G10E EH20 EH520	K20	G2F KS20 G2	VC2 VC28 VC29
	K30	IC28	K1 KMF	HTi20T	N10 N311	CQ22	H13A	875	G3	K30	G3	VC111 VC101

NOTE : The Grade Comparison Tables on pages 124, 125, 126 & 127 are based on published data and intended as a guide only. The data therein should not be assumed to be accurate equivalents. Some grades may be obsolete and are included for reference purposes.

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TUNGSTEN CARBIDE GRADES COMPARISON TABLE

COATED GRADES

Application Materials			DIJET	HITACHI	ISCAR	KENNAMETAL	MITSUBISHI	SANDVIK	SECO	SUMITOMO	TAEGUTEC	TUNGALOY	VALENITE
TURNING	STEEL	P01	JC110V JC5003	GM10 HC5000	IC428	KC910	UE6005	GC4015	TP1000 CMP	AC700G AC1000	TT1300	T9005 TD905	SV405 SV305
		P10	JC100V JC215V JC5003	GM8015 GM20 GM8020 GM10	IC9015 IC8048 IC570	KC9010 KC990 KC935 KC5010	UE6005 UE6010 UE6020 UC6010	GC4015 GC1525	TP1000 TP100 TP15 CP200	AC700G AC2000	T1500	TD9015 TD905 TD915	SV510 SV410 SV515
		P20	JC110V JC215V JC5015	GM8020 GM20 GM25	IC8048 IC9015	KC9125 KC9025 KC8050	UE6010 UE6020	GC4025 GC4015 GC1025	TP2000 TP1000 TP200	AC2000	TT2500	TD9015 T9025 TD915	SV515 SV415 SV525
		P30	JC215V JC325V JC5015	GM8035 CY250 HC844	IC9025 IC328	KC9040 KC5025 KC850	UE6025 US735	GC4035 GC5025	TP3000 TP2000 T25M	AC3000	TT2250	T9025 T9035 TD930	SV525 SV330 SV230
		P40	JC325V JC450V	GX30 CY250 HC844	IC635 IC328 IC228	KC9045 KC250	UE6035 US735	GC4035 GC235	TP400 TP40 CP500	AC3000 AC304	KT450	T9035 TD930	SV235 SV525 SV230
	STAINLESS STEEL	M10	JC110V	GM10 GM8015	IC570 IC520	KC9110 KC732	UE6010 US7020	GC2015 GC1525	TP100 TP100	EH10Z EH510Z	TT1300	TD915	VC929 SV510
		M20	JC215V JC1341	GM8020 GM20	IC907 IC507	KC8050 KC9225	US7020 UE6020	GC1025 GC2015	TP200 CP50	EH20Z EH520Z	TT2500	T6020	VC901 SV230
		M30	JC215V JC325V JC5015	GX30 CY9020	IC328 IC3028	KC9240 KC9040	UE6035 US735	GC2025 GC2035 GC235	TP3000 TP400 CP500	AC304 AC3000		T6030	VC901 SV415 SV230
	CAST IRON	K01	JC105V JC110V	GM3005	IC4028 IC9007	KC9315 KC910	UC5005 UC5015	GC3005		AC300G	TT1300	T5010	SV405 SV305
		K10	JC105V JC110V	GM3005 GM8015	IC8048 IC9015	KC5010 KC7310	UC5015 UE6010	GC3015 GC3005	TP100	AC700G EH10Z	TT1300	T5010 T5020	SV410 SV510
		K20	JC110V JC215V	GM8015	IC8048 IC328	KC8050 KC9120	UE6010	GC3025 GC4015	TP200 TX150	AC700G AC2000	TT1500	T5020	SV415 SV515
MILLING	STEELS		JC5015	CY250 CY15 HC844	IC950 IC520 IC328	KC792M KC994M KC725M	F7030 VP15TF VP30RT	GC4020 GC4030 GC4040	T350M T250M T200M	AC230 ACZ330 ACZ350	KT7030 KT7300 TT8020	T325 AH120 AH740	V1N VC935
	STAIN-LESS STEEL		JC5015 JC5030	CY250	IC328	KC994M KC721M KC725M	F7030 VP15TF VP30RT	GC1025 GC2030 GC2040	T350M T250M T200M	EH20Z ACZ350		T325 GH330 AH330	V1N VC935
	CAST IRON		JC3515 JC3511 JC610	CY10H HC830 CY100H	IC910	KC910 KC705M KC992M	F5010 F5020	GC3020 GC3040	T200M T150M	AC211 EH20Z ACZ310	TT6030	T325 GH330 AH330	VN8 VN5 VC928
THREADING				GM8015	IC908 IC250 IC228 IC220	KC730 KC710	VP20M US735	GC1020 GC4125	CP500 CP50	AC225	TT6010 TT7010 TT8010 TT9030	AH740 T313V	VC905 VC929

TUNGSTEN CARBIDE GRADES COMPARISON TABLE

CERMET GRADES

ISO Classification		DIJET	ISCAR	KENNAMETAL	KYOCERA	MITSUBISHI	SANDVIK	SUMITOMO	TAEGUTEC	TUNGALOY
P	P01	LN10 CX50	IC20N IC520N	KT125 HTX	TN30 PV30	AP25N		T110A	CT320 PV320	NS520 AT520
P	P10	LN10 CX50 NIT CX75	IC20N IC30N IC520N	KT315 KZ205 HT2 KT175	TN60 PV60	AP25N NX2525	CT5015 CT525	T2000Z T1200A	CT320 CT420	NS520 GT530 NS530
P	P20	CX50 NAT CX75 CX90	IC20N IC520N IC530N	KT175 HT5 PS5	TN60 PV90 TN90	AP25N NX2525 UP35N NX335	GC1525	T2000Z T1200A T130A T3000Z	CT420	NS530 AT530 GT530
P	P30	CX90 CX99 SUZ	IC30N IC530N	HT7	TN60 TC60M PV90	VP45N		T3000Z T250A	CT520	NS530 NS540
M	M10	LN10		KT315	TN60	AP25N	CT5015	T110A		NS520
M	M20	CX50 NIT		KT175 HT2	TN60 PV60	AP25N NX2525	CT530 GC1525	T2000Z T1200A		NS530 N308
M	M30	CX75						T250A		NS540
K	K01	LN10	IC520N IC20N		TN30 PV30	AP25N NX2525	CT515 CT5015	T110A	CT320 PV320	NS520 AT520
K	K10	LN10	IC520N IC20N	KT315 HTX	TN60 PV60	AP25N NX2525	CT525	T2000Z T1200A	CT320	NS520
K	K20	NIT	IC520N IC20N			AP25N NX2525			CT520	

CERAMIC GRADES

Composition	CERASIV	ISCAR	KENNAMETAL	KYOCERA	NTK	MITSUBISHI	SANDVIK	SUMITOMO	TAEGUTEC	TUNGALOY
Si_3N_4	SL100 SL150 SL200	IS8	Kyon2000 Kyon3000 Kyon3500	KS6000 KS8000 KS500	SX1 SX2	XE515 X520	CC6090 CC670	NS260 NS130	AS10	FX105
AL_2O_3	SN60 SN80	IN11	K060	AZ5000 SN60	CX3		CC620	W80	AW20	LXA
AL_2O_3-TiCN	SH1		Kyon4400		HC4	XD105			AB20	LX11
AL_2O_3-TiC	SH20F		K090	A65	HC2	XD202	CC650	NB90S	AB30	LX21
Si_3N_4-CVD	SL250C	IS80	Kyon3400		SP2	XC1510	GC1930	NS260C	SC10	TF110

TUNGSTEN CARBIDE GRADES COMPARISON TABLE

CBN (CUBIC BORON NITRIDE)

	Application	DE BEERS	GENERAL ELECTRIC	ISCAR	KENNAMETAL	MITSUBISHI	SANDVIK	SECO	SUMITOMO	TAEGUTEC	TUNGALOY
K	Cast Iron	DBC80	BZN6000 BZN7000S	IB90 IB90A IB55	KD120 KD200	MB710 MB730	CB50	CBN300 CBN350	BN100 BN600 BN500	KB90 KB90A KB65	BX950 BX930 BX850
S	Super Alloys		BZN6000	IB90	KD120	MB730 MB80			BN600 BN250	KB90	BX950 BX450 BX480
H	Hardened Steel	DBC80	BZN8200	IB55 IB90 IB50	KD050 KD081 KD120 KB6325	MB810 MB825 MB8025 MB820 MB835	CB50 CB20 CB7020	CBN10 CBN100 CBN300 CBN350	BNX10 BN200 BN250 BNX20 BNX25	TB650 KB90 KB50	BX310 BX330 BX360 BX380 BXC50

PCD (POLYCRYSTALLINE DIAMOND COMPACTS)

Grade	DE BEERS	GENERAL ELECTRIC	ISCAR	KYOCERA	KENNAMETAL	MITSUBISHI	SANDVIK	SUMITOMO	TAEGUTEC	TUNGALOY
Fine	Syndite 002	Compax 1600	ID4 ID6	KD050	KPD002	MD230	CD10	DA2200	KP100	DX120
Medium	Syndite 010	Compax 1300	ID5	KD100	KPD010	MD220 MD205		DA150 DA100	KP300	DX140 DX160
Coarse	Syndite 025	Compax 1500		KPD025				DA90	KP500	DX180

Si_3N_4	- Silicon Nitride	TiC	- Titanium Carbide
AL_2O_3	- Aluminium Oxide	CVD	- Chemical Vapour Deposition
TiCN	- Titanium Carbonitride	PVD	- Physical Vapour Deposition

CERMET - A cutting tool material that is a composite of Titanium Carbide and Titanium Nitride and designed for light roughing to high speed finishing.

CERAMIC - A metal oxide composite with edge strength well suited for finish-machining materials with a hardness upto 65 Rc.

PCBN - Polycrystalline Cubic Boron Nitride (next hardest material to diamond) that is designed for finish / rough machining of hardened materials upto 70 Rc.

PCD - Polycrystalline Diamond particles tightly sintered onto a WC base and designed for machining highly abrasive non-ferrous and non-metal materials at speeds upto 2000 m/min.

TUNGSTEN CARBIDE INSERT IDENTIFICATION (TURNING)

TNMG 160408R-2G - Grade

T	N	M	G
1	2	3	4

1 Insert Shape

Symbol	Insert Shape
A	Parallelogram 85°
B	Parallelogram 82°
C	Rhombic 80°
D	Rhombic 55°
E	Rhombic 75°
F	Rhombic 50°
H	Hexagon
K	Parallelogram 55°
L	Rectangle
M	Rhombic 86°
O	Octagon
P	Pentagon
R	Round
S	Square
T	Triangle
V	Rhombic 35°
W	Trigon

2 Relief Angle

Symbol	Relief Angle	Symbol	Relief Angle
A	3°	F	25°
B	5°	G	30°
C	7°	N	0°
D	15°	P	11°
E	20°	O	Special

3 Tolerance

Class	Tol. ± 'm' (mm)	Tol. ± 's' (mm)	Tol. ± 'd' (mm)
A	0.005	0.025	0.025
C	0.013	0.025	0.025
E	0.025	0.025	0.025
F	0.005	0.025	0.013
G	0.025	0.130	0.025
H	0.013	0.025	0.013
J	0.050	0.025	.05 ~ .13
K	0.013	0.025	.05 ~ .13
L	0.025	0.025	.05 ~ .13
M	.08 ~ .18	0.130	.05 ~ .13
N	.08 ~ .18	0.025	.05 ~ .13
U	.13 ~ .38	0.130	.08 ~ .25

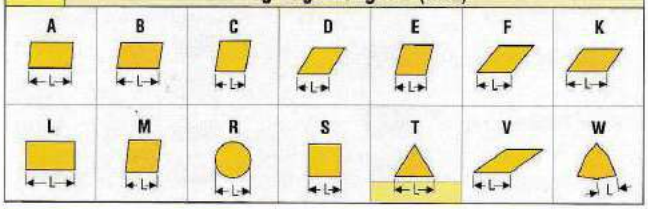
4 Fixing / Chip Breaker

Symbol	Feature	Symbol	Feature
A		N	
B		Q	
C		R	
F		T	
G		U	
H		W	
J		X	Special
M			

TUNGSTEN CARBIDE INSERT IDENTIFICATION (TURNING)

16	04	08	(F)*	(R)#	2G
5	6	7	8	9	10

5 Cutting Edge Length L (mm)



6 Thickness

Symbol	Thickness (S)
01	1.59
T1	1.98
02	2.38
T2	2.78
03	3.18
T3	3.97
04	4.76
05	5.56
06	6.35
07	7.94
09	9.52

7 Radius

Symbol	Nose Rad.
00	Sharp Pt.
01	0.1
02	0.2
04	0.4
08	0.8
12	1.2
16	1.6
20	2.0
24	2.4
28	2.8
32	3.2
00 M0	Round Insert

8 Edge*

Symbol	Figure
E	Hone
F	Sharp
S	Chamfer + Hone
T	Chamfer

*Most manufacturers generally omit this Cutting Edge Symbol.

9 Feed#

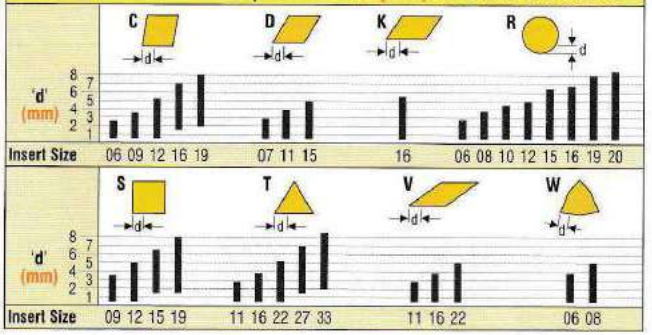
Symbol	Figure
R Right	
L Left	
N Neutral	

Most manufacturers omit this symbol when the insert is Neutral.

10 Chip Breaker

This Symbol is reserved for Mfr.'s Chip Breaker Design.

Recommended Max. Depth of Cut 'd' (mm) for Standard Inserts



TUNGSTEN CARBIDE INSERT IDENTIFICATION (MILLING)

SEKN 1203AFTN - Grade

S	E	K	N
1	2	3	4

1 Insert Shape

Symbol	Insert Shape
A	Parallelogram 85°
B	Parallelogram 82°
C	Rhombic 80°
H	Hexagon
L	Rectangle
M	Rhombic 86°
O	Octagon
P	Pentagon
R	Round
S	Square
T	Triangle
W	Trigon

2 Relief Angle

Symbol	Relief Angle	Symbol	Relief Angle
A	3°	F	25°
B	5°	G	30°
C	7°	N	0°
D	15°	P	11°
E	20°	O	Special

3 Tolerance

Class	Tol. ± 'M' (mm)	Tol. ± 's' (mm)	Tol. ± 'd' (mm)
A	0.005	0.025	0.025
C	0.013	0.025	0.025
E	0.025	0.025	0.025
G	0.025	0.130	0.025
H	0.013	0.025	0.013
J	0.050	0.025	.05 ~ .13
K	0.013	0.025	.05 ~ .13
M	.08 ~ .18	0.130	.05 ~ .13
U	.13 ~ .38	0.130	.08 ~ .25

4 Fixing / Chip Breaker

Symbol	Feature	Symbol	Feature
A		Q	
B		R	
F		T	
M		W	
N		X	Special

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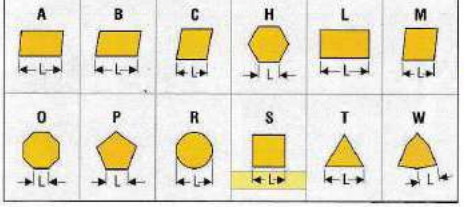
TUNGSTEN CARBIDE INSERT IDENTIFICATION (MILLING)

12	03	A	F	T	N
5	6	7	8	9	10

5 Cutting Edge Length L (mm)



6 Thickness

Symbol	Thickness (S)
02	2.38
03	3.18
T3	3.97
04	4.76
05	5.56
06	6.35

7 Cutting Angle

Symbol	Cutting Angle (α)
A	45°
D	60°
E	75°
F	85°
P	90°
X	65°
Z	Special

Metric Series (Nose Radius)

Symbol	Nose Radius
00	Sharp Point
01	0.1
02	0.2
04	0.4
08	0.8
12	1.2
16	1.62
M0	Round Insert

8 Relief ∠

Symbol	Relief ∠(β)
A	3°
B	5°
C	7°
D	15°
E	20°
F	25°
G	30°
N	0°
P	11°
R	10°
S	14°
T	22°
U	23°
Z	Special

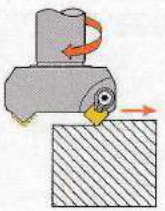
Example:

	1	2	3	4	5	6	7	8	9	10
Std. Series	S	E	K	N	12	03	A	F	T	N
Metric Series	0	E	K	T	06	06	08		S	N

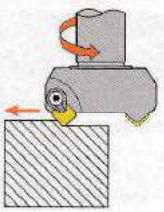
9 Edge

Symbol	Figure
E	Hone
F	Sharp
S	Chamfer + Hone
T	Chamfer

10 Direction of Cutting



R Right Rotation



L Left Rotation

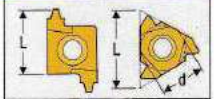
N Neutral Right & Left Rotation

TUNGSTEN CARBIDE INSERT IDENTIFICATION (THREADING)

16ER1.0 ISO-A1 - Grade

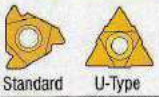
16	E	R	1.0	ISO	A1
1	2	3	4	5	6

1 Edge Length



L (mm)	d (mm) - ic
06	3.97
08	4.76
11	6.35
16	9.525
22	12.70
27	15.875

2 Application

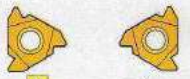


Symbol	Application
E	External
N	Internal
U	U-Type

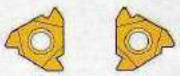
NOTE :
Some manufacturers use "I" to denote Internal.

3 Insert Version

External Threading



Internal Threading



4 Thread Pitch

Full Profile (mm)				Full Profile (tpi)					Part Profile	
0.5	0.7	0.75	0.8	48	40	32	24	20	A = 0.5 - 1.5 mm	48 - 16 tpi
1.0	1.25	1.5	1.75	18	16	14	13	12	AG = 0.5 - 3.0 mm	48 - 8 tpi
2.0	2.5	3.0	4.0	11	10	9	8	7	G = 1.75 - 3.0 mm	18 - 8 tpi
4.5	5.0	5.5	6.0	6	5	4.5	4	3	N = 3.5 - 5.0 mm	7 - 5 tpi
8.0	10.0	12.0	14.0	2.5	2				K = 5.5 - 8.0 mm	4.5 - 3 tpi

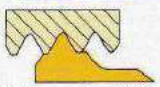
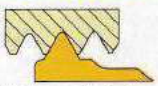
5 Thread Form

Symbol	Profile	Symbol	Profile	Symbol	Profile
60	= V profile 60°	BUT2.5	= Buttress Fig.2.5	RND	= Round DIN 405
55	= V profile 55°	BUT2.6	= Buttress Fig.2.6	STACME	= Stub Acme
ABUT	= American Buttress	BSPT	= Whitworth Taper	TR	= Trapezoidal DIN 103
ACME	= Am.Acme-G	EL	= Extreme Line Casing	UN	= American Unified
API	= American Pet. Inst.	H90	= Hughes	UNJ	= UN-Controlled Root
API RD	= API Rd. Casing	ISO	= ISO, Metric	VAM	= Vam Vallourec
BUT	= API Buttress	NPT	= National Pipe Taper	W	= Whitworth (BSW)

Refer pages 15-19 for Basic Thread Profile details.

6 No. of Teeth / Chip Breaker

Optional : To Manufacturer's Discretion

Full Profile	Partial Profile	
		Single Tooth Insert
• Workpiece may be slightly oversize as insert 'Tops' the thread. • No subsequent thread deburring is necessary.	• Workpiece needs to be accurately pre-machined. • One insert covers a wide range of pitches.	Multi Tooth Insert

QUICK VISUAL IDENTIFICATION OF TUNGSTEN CARBIDE INSERT SHAPES

The following is a list of some of the common basic shapes of Tungsten Carbide Inserts that may be found in most engineering workshops.

It is by no means a comprehensive list and is provided as a starting point for Insert identification.

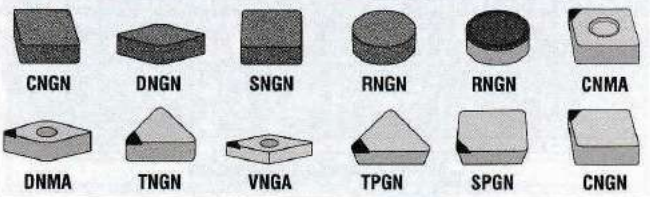
Refer pages 128 to 131 for detailed information regarding Insert identification.

NOTE : Chipbreaker shapes and designs vary considerably between manufacturers.

Common – Turning / Milling Inserts

(Threading Inserts)

Common – Ceramic / Cermet / PCBN / PCD Inserts



134 TUNGSTEN CARBIDE (EXTERNAL) TOOLHOLDER IDENTIFICATION (TURNING)

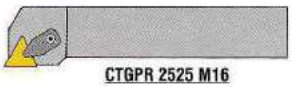
C	T	G	P	R	25	25	M	16	□
1	2	3	4	5	6	7	8	9	10

1 Clamping

Insert Clamping System

- C - Clamp Lock
- M - Clamp + Pin Lock
- P - Pin Lock
- S - Screw Lock
- W - Wedge Lock

External Turning Toolholder

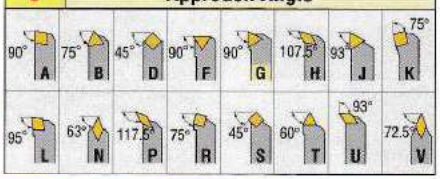


CTGPR 2525 M16

2 Insert Shape

- A - Parallelogram 85°
- B - Parallelogram 82°
- C - Rhombic 80°
- D - Rhombic 55°
- E - Rhombic 75°
- F - Rhombic 50°
- H - Hexagon
- K - Parallelogram 55°
- L - Rectangle
- M - Rhombic 86°
- O - Octagon
- P - Pentagon
- R - Round
- S - Square
- T - Triangle
- V - Rhombic 35°
- W - Trigon

3 Approach Angle



4 Relief ∠

- A - 3°
- B - 5°
- C - 7°
- D - 15°
- E - 20°
- F - 25°
- G - 30°
- N - 0°
- P - 11°
- O - Special

5 Version

R - Right | L - Left | N - Neutral

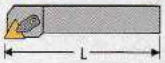
6 Shank

Shank Height - (mm)

7 Shank

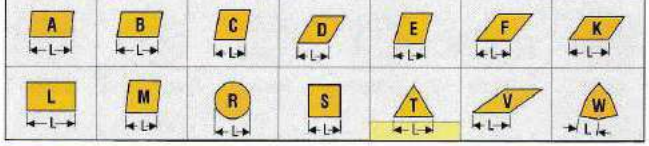
Shank Width - (mm)

8 Tool Length (mm)



A - 32	F - 80	P - 170
C - 50	H - 100	R - 200
D - 60	K - 125	S - 250
E - 70	M - 150	T - 300

9 Cutting Edge Length L (mm)



10 Manufacturer's Designation

135 TUNGSTEN CARBIDE (INTERNAL) TOOLHOLDER IDENTIFICATION (BORING)

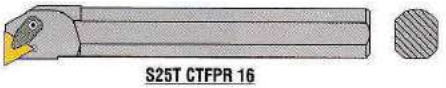
S	25	T	C	T	F	P	R	16	□
1	2	3	4	5	6	7	8	9	10

1 Type

Boring Bar Shank

- A - Steel with Coolant Hole
- C - Carbide Shank
- E - Coolant through Carbide Shank
- S - Steel Shank

Boring Bar



S25T CTFPR 16

2 Shank

Shank Diameter 'd' (mm)

3 Tool Length (mm)

J - 110	N - 160	S - 250
K - 125	P - 170	T - 300
L - 140	Q - 180	U - 350
M - 150	R - 200	V - 400

4 Clamping

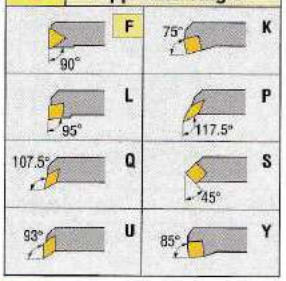
Insert Clamping System

- C - Clamp Lock
- M - Clamp + Pin Lock
- P - Pin Lock
- S - Screw Lock
- W - Wedge Lock

5 Insert Shape

- A - Parallelogram 85°
- B - Parallelogram 82°
- C - Rhombic 80°
- D - Rhombic 55°
- E - Rhombic 75°
- F - Rhombic 50°
- H - Hexagon
- K - Parallelogram 55°
- L - Rectangle
- M - Rhombic 86°
- O - Octagon
- P - Pentagon
- R - Round
- S - Square
- T - Triangle
- V - Rhombic 35°
- W - Trigon

6 Approach Angle



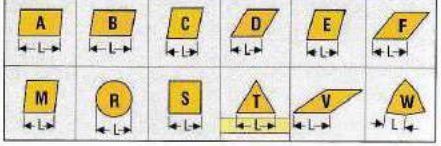
7 Relief ∠

- A - 3°
- B - 5°
- C - 7°
- D - 15°
- E - 20°
- F - 25°
- G - 30°
- N - 0°
- P - 11°
- O - Special

8 Version

R - Right Hand | L - Left Hand

9 Cutting Edge Length L (mm)



10 Manufacturer's Designation

TUNGSTEN CARBIDE TOOLHOLDER IDENTIFICATION (THREADING)

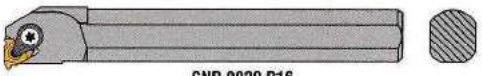
C	E	R	2020	K	16	□
1	2	3	4	5	6	7

External Threading Toolholder

CER 2020 K16

C	N	R	0020	P	16	□
1	2	3	4	5	6	7

Internal Threading Bar



CNR 0020 P16

1 Clamping

Insert Clamping System

C - Clamp System

S - Screw System

2 Application

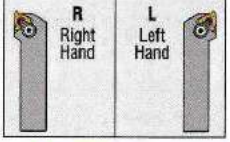
External / Internal

E - External Threading

N - Internal Threading

NOTE : Some manufacturers use "I" to denote Internal.

3 Version



4 Shank Size

External Toolholder

Shank - h x b

Example :

2020 = 20 x 20 mm

Internal Toolholder

Shank - Diameter d

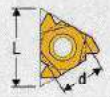
Example :

0020 = 20 mm diameter.

5 Tool Length

Symbol	Length (mm)
D	60
F	80
H	100
K	125
L	140
M	150
P	170
R	200
S	250
T	300
U	350
V	400

6 Insert Size

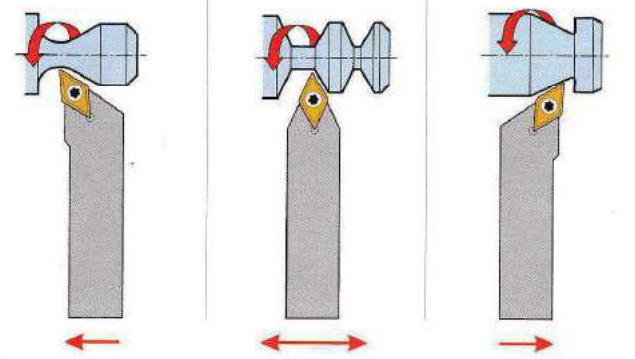


L (mm)	d (mm) - ic
06	3.97
08	4.76
11	6.35
16	9.525
22	12.70
27	15.875

7 No. of Teeth / Chip Breaker

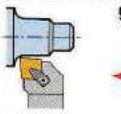
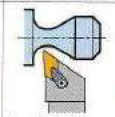
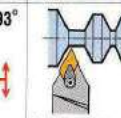
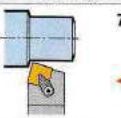
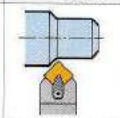
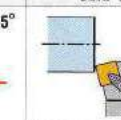
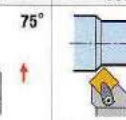
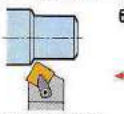
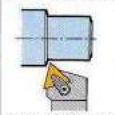
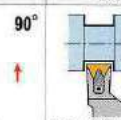
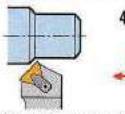
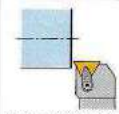
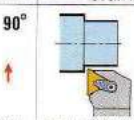
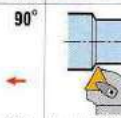
Optional : To Manufacturer's Discretion

TUNGSTEN CARBIDE TOOLHOLDER SELECTION / APPLICATION



NOTE : For Toolholder Identification - refer page 134

Toolholders with C Clamping System (Top Clamp)

CCLNR 2525 M12	CKJN R/L	CKNN R/L	CRSN R/L
			
Insert - CNGN	Insert - KNUX	Insert - KNUX	Insert - RNGN
CSBP R/L	**CSDPN**	**CSKP R/L**	**CSSP R/L**
			
Insert - SPMR, SPUN	Insert - SPMR, SPUN	Insert - SPMR, SPUN	Insert - SPMR, SPUN
CSTP R/L	**CTBP R/L**	**CTCPN**	**CTCP R/L**
			
Insert - SPMR, SPUN	Insert - TPMR, TPUN, TPUX	Insert - TPMR, TPUN	Insert - TPMR, TPUN
CTDP R/L	**CTFP R/L**	**CTGP R/L**	**CTTP R/L**
			
Insert - TPMR, TPUN, TPUX	Insert - TPMR, TPUN, TPUX	Insert - TPMR, TPUN, TPUX	Insert - TPMR, TPUN, TPUX

TUNGSTEN CARBIDE TOOLHOLDER SELECTION / APPLICATION

Toolholders with M (Multi) Clamping System (Top Clamp + Pin Lock)

MCLN R/L — 95° — Insert - CNMA, CNMM, CNMG

MDJN R/L — 93° — Insert - DNGN

MRGN R/L — 90° — Insert - RNGA, RNMX

MSSN R/L — 45° — Insert - SNMG

MTENN — 60° — Insert - TNMG, TNMX

MTGN R/L — 90° — Insert - TNMG, TNMX

MTJN R/L — 93° — Insert - TNMG, TNMX

MTNNN — 63° — Insert - TNMG, TNMX

MVJN R/L — 93° — Insert - VNMG

MVQN R/L — 117°30' — Insert - VNMG

MVVNN — 72°30' — Insert - VNMG

MWLN R/L — 95° — Insert - WNMG

Toolholders with P Clamping System (Pin Lock)

PCBN R/L — 75° — Insert - CNMA, CNMM, CNMG

PCFN R/L — 90° — Insert - CNMA, CNMM, CNMG

PCKN R/L — 75° — Insert - CNMA, CNMM, CNMG

PCMNN — 50° — Insert - CNMA, CNMM, CNMG

PCLN R/L — 95° — Insert - CNMA, CNMM, CNMG

PCSN R/L — 45° — Insert - CNMA, CNMM, CNMG

PDJN R/L — 93° — Insert - DNMG, DNMX

PDNN R/L — 63° — Insert - DNMG, DNMX

PRDCN — 90° — Insert - RCMT

PRSC R/L — 90° — Insert - RCMT

PRSN R/L — 90° — Insert - RNMG

PSBN R/L — 75° — Insert - SNMG

PSDNN — 45° — Insert - SNMG

PSKN R/L — 75° — Insert - SNMG

PSSN R/L — 45° — Insert - SNMG

PTDN R/L — 45° — Insert - TNMG, TNMX

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TUNGSTEN CARBIDE TOOLHOLDER SELECTION / APPLICATION

Toolholders with P Clamping System (Pin Lock)...contd.

PTFN R/L — 90° — Insert - TNMG, TNMX

PTGN R/L — 90° — Insert - TNMG, TNMX

PTTN R/L — 60° — Insert - TNMG, TNMX

PWLN R/L — 95° — Insert - WNMG

Toolholders with S Clamping System (Screw Lock)

SCAC R/L — 90° — Insert - CCGT, CCMT, CCMW

SCLC R/L — 95° — Insert - CCGT, CCMT, CCMW

SCRC R/L — 75° — Insert - CCGT, CCMT, CCMW

SDJC R/L — 93° — Insert - DCGT, DCMT, DCMW

SDNCN — 62°30' — Insert - DCGT, DCMT, DCMW

SRDCN — 90° — Insert - RCMT

SRSC R/L — 90° — Insert - RCMT

SSBC R/L — 75° — Insert - SCGT, SCMT, SCMW

SSDCN — 45° — Insert - SCGT, SCMT, SCMW

SSSC R/L — 45° — Insert - SCGT, SCMT, SCMW

STAC R/L — 90° — Insert - TCGT, TCMT, TCMW

STDC R/L — 45° — Insert - TCGT, TCMT, TCMW

STFC R/L — 90° — Insert - TCGT, TCMT, TCMW

STGC R/L — 90° — Insert - TCGT, TCMT, TCMW

STJC R/L — 93° — Insert - TCGT, TCMT, TCMW

STTC R/L — 60° — Insert - TCGT, TCMT, TCMW

SVHC R/L — 107°30' — Insert - VCGT, VCMT

SVJB R/L — 93° — Insert - VBMM

SVJC R/L — 93° — Insert - VCGT, VCMT

SVLC R/L — 95° — Insert - VCMT

SVVB R/L — 72°30' — Insert - VBMM

SVVC R/L — 72°30' — Insert - VCGT, VCMT

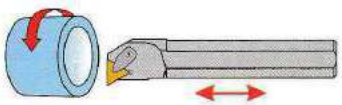
SVXC R/L — 113° — Insert - VCMT

SVZC R/L — 100° — Insert - VCGT, VCMT

TUNGSTEN CARBIDE BORING BAR SELECTION / APPLICATION

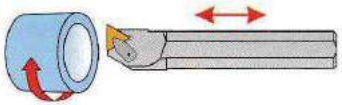
Boring Bar Feed Direction - Hand of Tool

Right Hand Boring Bar (R)



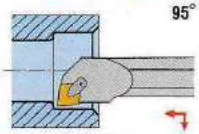
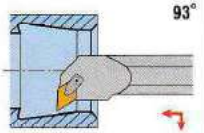
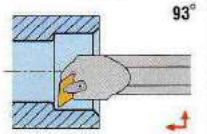
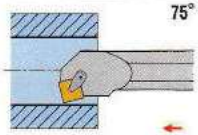
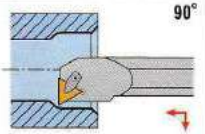
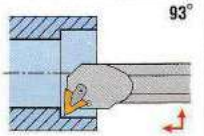
Direction of Tool Travel (Feed)

Left Hand Boring Bar (L)

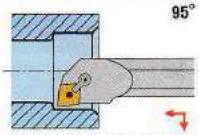
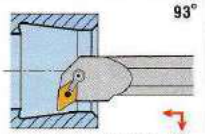
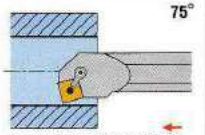
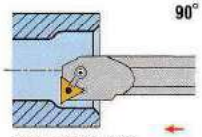
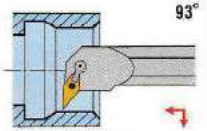
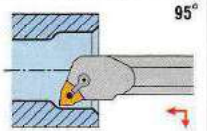


NOTE : For Boring Bar Identification - refer page 135

Boring Bars with C Clamping System (Top Clamp)

S40T-CCLNR12	-CDUN R/L	-CKUN R/L
95°	93°	93°
		
Insert - CNGN, CNGX	Insert - DNGN, DNGX	Insert - KNUX
-CSKP R/L	**-CTFP R/L**	**-CTUP R/L**
75°	90°	93°
		
Insert - SPMR, SPUN	Insert - TPMR, TPUN, TPUX	Insert - TPMR, TPUN, TPUX

Boring Bars with M (Multi) Clamping System (Top Clamp + Pin Lock)

-MCLN R/L	-MDUN R/L	-MSKN R/L
95°	93°	75°
		
Insert - CNMA, CNMG, CNMM	Insert - DNMA, DNMG, DNMX	Insert - SNMA, SNMG, SNMX
-MTFN R/L	**-MVVN R/L**	**-MWLN R/L**
90°	93°	95°
		
Insert - TNMG, TNMX	Insert - VNMA, VNMG	Insert - WNMG

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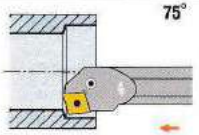
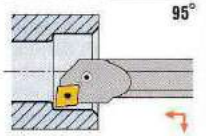
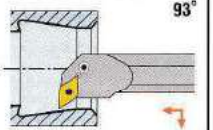
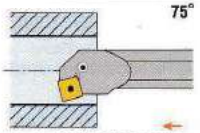
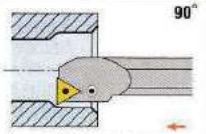
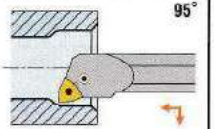
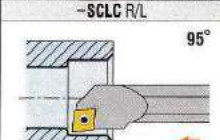
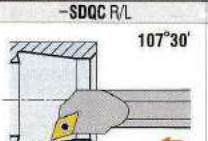
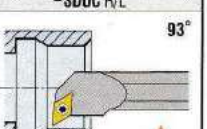
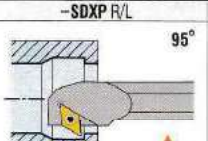
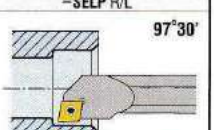
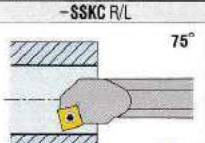
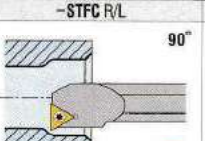
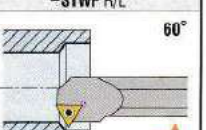
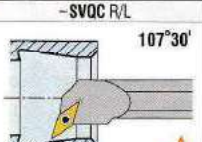
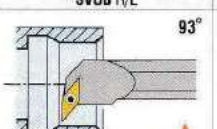
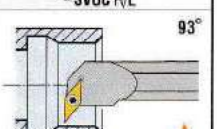
TUNGSTEN CARBIDE BORING BAR SELECTION / APPLICATION

Boring Bars with P Clamping System (Pin Lock)

-PCKN R/L	-PCLN R/L	-PDUN R/L
75°	95°	93°
		
Insert - CNMA, CNMG, CNMM	Insert - CNMA, CNMG, CNMM	Insert - DNMA, DNMG, DNMX
-PSKN R/L	**-PTFN R/L**	**-PWLN R/L**
75°	90°	95°
		
Insert - SNMA, SNMG, SNMX	Insert - TNMA, TNMG, TNMX	Insert - WNMG

Boring Bars with S Clamping System (Screw Lock)

-SCLC R/L	-SDQC R/L	-SDUC R/L
95°	107°30'	93°
		
Insert - CCGT, CCMT, CCMW	Insert - DCGT, DCMT, DCMW	Insert - DCGT, DCMT, DCMW
-SDXP R/L	**-SELC R/L**	**-SELP R/L**
95°	97°30'	97°30'
		
Insert - DCGT, DCMT, DCMW	Insert - ECMT	Insert - EPMT, EPMW, EPMX
-SSKC R/L	**-STFC R/L**	**-STWP R/L**
75°	90°	60°
		
Insert - SCGT, SCMT, SCMW	Insert - TCGT, TCMT, TCMW	Insert - TPGX, TPMT
-SVQC R/L	**-SVUB R/L**	**-SVUC R/L**
107°30'	93°	93°
		
Insert - VCGT, VCMT	Insert - VBMM	Insert - VCGT, VCMT

ABBREVIATIONS USED IN ENGINEERING DRAWINGS

Common International Engineering Standards

INTERNATIONAL	ISO	Intl. Organisation for Standardisation
AUSTRALIA	AS	Australian Standards
FRANCE	AFNOR	Association Française de Normalisation
GERMANY	DIN	Deutsches Institut für Normung
	WR	German Material Number (Werkstoff No.)
ITALY	UNI	Ente Nazionale Italiano di Unificazione
JAPAN	JIS	Japanese Industrial Standards
KOREA	KS	Korean Standards
SWEDEN	SS	Swedish Standards
UK	BS	British Standards
USA	AISI	American Iron and Steel Institute
	ANSI	American National Standards Institute
	ASTM	American Society for Testing and Materials
	SAE	Society of Automotive Engineers
	AMS	Aerospace Material Specifications

Common Engineering Drawing Abbreviations

Abbreviation	Term	Abbreviation	Term
A/F	Across Flats	INT	Internal
ASSY	Assembly	I/D	Internal diameter
CM	Centimetres	KG	Kilogram
CL or L	Centre line	LH	Left hand
CHAM	Chamfered	LG	Long
CH HD	Cheese head	M/C	Machine
CSK	Countersunk	MATL	Material
CSK HD	Countersunk head	MAX	Maximum
C'BORE	Counterbore	M	Metre
CYL	Cylinder or Cylindrical	MM	Millimetre
DATUM	Datum system	MIN	Minimum
°	Degree (of angle)	'	Minute (of angle)
Dia or Ø	Diameter	NTS	Not to scale
DIM	Dimension	NO.	Number
DRG	Drawing	O/D	Outside diameter
EQUI SP	Equally Spaced	PCD	Pitch circle diameter
EXT	External	LB	Pound
FIG	Figure	RAD or R	Radius
FT or '	Foot	RPM	Revolutions per minute
GAL	Gallon	RH	Right hand
GALV	Galvanized	RD HD	Round head
HRA	Hardness Rockwell A scale	SCR	Screwed
HRB	Hardness Rockwell B scale	''	Second (of angle)
HRC	Hardness Rockwell C scale	SK	Sketch
HRD	Hardness Rockwell D scale	SPEC	Specification
HRE	Hardness Rockwell E scale	SPH	Spherical
HB	Hardness Brinell	SQ	Square
HV	Hardness Vickers	STD	Standard
HEX	Hexagon	SWG	Standard (imperial) wire gauge
HEX HD	Hexagon head	THD	Thread
HYD	Hydraulic	TPI	Thread per inch
IN or ''	Inch	VOL	Volume
INSUL	Insulated or insulation	WT	Weight

STANDARDS FOR ENGINEERING DRAWINGS

Mathematical Symbols

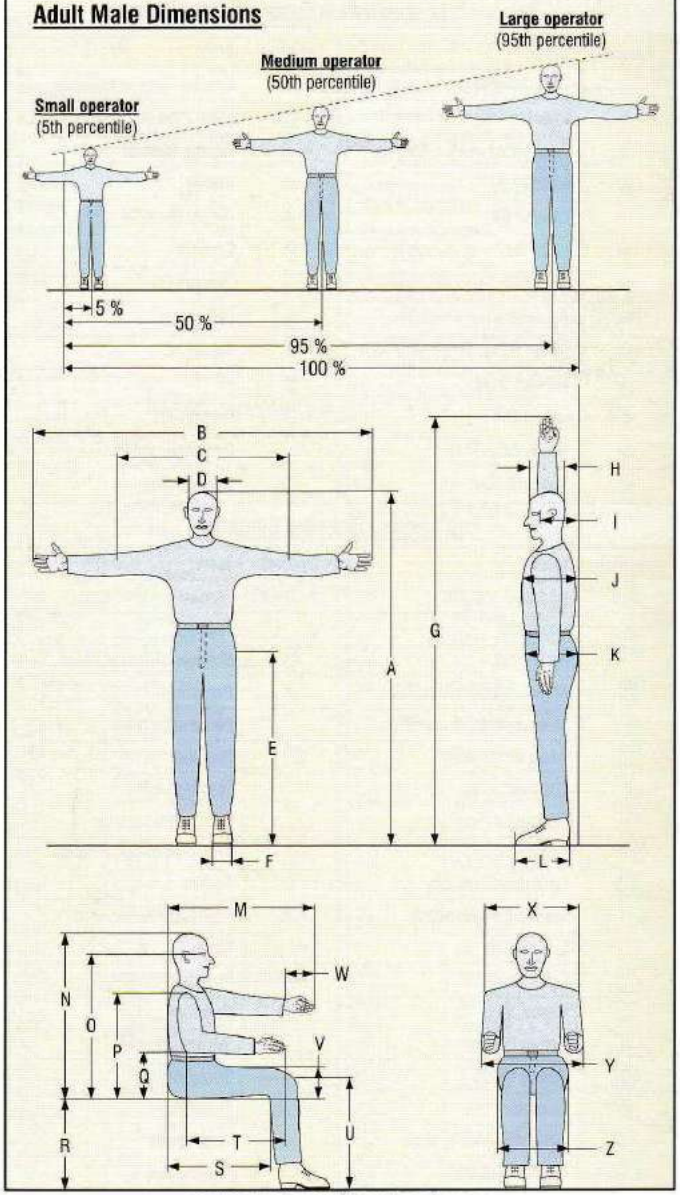
Symbol	Term	Symbol	Term
+	Plus or Positive	≥	Greater Than or Equal To
−	Minus or Negative	≤	Less Than or Equal To
±	Plus/Minus or Pos./Neg.	√	Square Root Of
X	Multiply By	∞	Infinity
÷	Divided By	∝	Proportional To
=	Equal To	Σ	Sum Of
≠	Not Equal To	∏	Product Of
≈	Approximately Equal To	Δ	Difference
~	Of the Order Of / Similar To	∴	Therefore
>	Greater Than	π	Pi
<	Less Than	∥	Parallel To
≯	Not Greater Than	⊥	Perpendicular To
≮	Not Less Than	:	Is To (Ratio)

Engineering Drawing Symbols

Symbol	Term	Symbol	Term
	All round - profile	⌖ 0.5 Ⓜ A B C	Feature control frame
∠	Angularity	▱	Flatness
⌒	Arc length	7X	Number of times/places
Ⓜ	At max. material condition	//	Parallelism
Ⓛ	At least material condition	⊥	Perpendicularity
35	Basic dimensions	⌖	Position
↗	Circular runout	⌒	Profile of a line
○	Circularity	⌓	Profile of a surface
▷	Conical taper	Ⓟ	Projected tolerance zone
◎	Contricity/Coaxiality	R	Radius
⌴	Counterbore/Spotface	(40)	Reference dimensions
⌵	Countersink	◺	Slope
⌭	Cylindricity	SØ	Spherical diameter
↧	Depth/Deep	SR	Spherical radius
-A-	Datum feature	□	Square (shape)
A1	Datum target	—	Straightness
Ø	Diameter	⥤	Symmetry
10	Dimension not to scale	×	Target point
	Dimension origin	↗	Total runout

ADULT PHYSICAL DIMENSIONS

Adult Male Dimensions



ADULT PHYSICAL DIMENSIONS

(Refer Page 144)

Symbol.	Designation	Small Operator (5th Percentile) Weight		Medium Operator (50th Percentile) Weight		Large Operator (95th Percentile) Weight	
		55 kgs	121.25 lbs	76.5 kgs	168.65 lbs	98 kgs	216.05 lbs
		(mm)	(inch)	(mm)	(inch)	(mm)	(inch)
A.	Height (with shoes)	1550	61.02"	1715	67.52"	1880	74.0 2"
B.	Arm span	1585	62.40"	1750	68.90"	1920	75.59"
C.	Arm span, elbows folded	850	33.46"	950	37.40"	1050	41.34"
D.	Head width	140	5.51"	152	5.98"	165	6.50"
E.	Hip point to floor	837	32.95"	927	36.50"	1016	40.00"
F.	Shoe width	95	3.74"	105	4.13"	115	4.53"
G.	Overhead reach	1900	74.80"	2100	82.68"	2300	90.55"
H.	Head length	170	6.69"	188	7.40"	205	8.07"
I.	Eye to back	170	6.69"	188	7.40"	205	8.07"
J	Chest depth	210	8.27"	245	9.65"	280	11.02"
K.	Abdominal depth	210	8.27"	255	10.04"	300	11.81"
L.	Shoe length	250	9.84"	285	11.22"	320	12.60"
M.	Anterior arm reach	750	29.53"	825	32.48"	900	35.43"
N.	Chest height	800	31.50"	880	34.65"	960	37.80"
O.	Eye height	690	27.17"	765	30.12"	840	33.07"
P.	Shoulder height	530	20.87"	590	23.23"	650	25.59"
Q.	Elbow height	200	7.87"	235	9.25"	270	10.63"
R.	Horizontal sitting height	400	15.75"	445	17.52"	490	19.29"
S.	Back to calf	420	16.54"	470	18.50"	520	20.47"
T.	Forearm to hand	410	16.14"	460	18.11"	510	20.08"
U.	Knee height (with shoes)	500	19.69"	560	22.05"	620	24.41"
V.	Thigh thickness	120	4.72"	145	5.71"	170	6.69"
W.	Hand length	170	6.69"	188	7.40"	205	8.07"
X.	Shoulder width	360	14.96"	440	17.32"	500	19.69"
Y.	Elbow to elbow	385	15.16"	450	17.72"	515	20.28"
Z.	Hip width	320	12.60"	365	14.37"	410	16.14"

Source : Data compiled from ISO 3411:1999 Human Physical Dimensions of Operators.

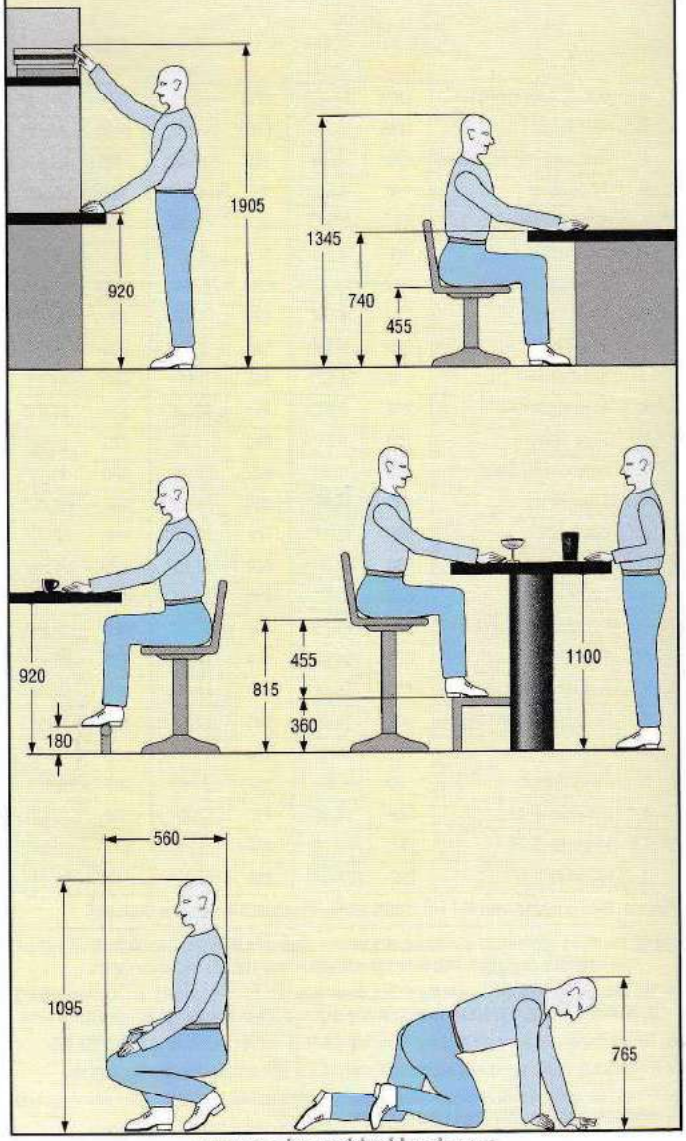
NOTE: The above information is intended as a general guide only and varies significantly throughout the world. It is provided to help in the basic design of workstations and equipment.

- The 50th percentile adult male in the United States between 20-65 years old, is 1755 mm (69.1") tall & weighs 78.4 kgs (172 lbs). This equates to approx. 2-3% > than the figures in the above table.
- The worldwide average male height is 1650 mm (64.96") and for women is 1537 mm (60.5").
- A wheelchair user's eye level is approx. 370 mm (14.6") below that of the standing person.
- Wheelchair users need a minimum aisle clearance of approx. 800 mm (31.5") and a turning circle of between 1500 mm (59") and 1700 mm (67").

ADULT PHYSICAL DIMENSIONS

Typical Furniture Measurements based on 50th Percentile Male

Dimensions in mm



G-CODE ADDRESSES USED IN NUMERICAL CONTROL

G-Code	Description
G00	Denotes point to point rapid traverse operations.
G01	Linear interpolation.
G02	Circular interpolation -- clockwise movement.
G03	Circular interpolation -- counter-clockwise movement.
G04	Dwell -- a programmed time delay.
G05	Unassigned.
G06	Parabolic interpolation.
G07	Used for programming with cylindrical diameter values.
G08	Programmed acceleration.
G09	Programmed deceleration.
G10-G12	Unassigned.
G13-G16	Axis selection.
G17	X-Y plane selection.
G18	X-Z plane selection.
G19	Y-Z plane selection.
G20-G32	Unassigned.
G33	Thread cutting, constant lead.
G34	Thread cutting, increasing lead.
G35	Thread cutting, decreasing lead.
G36-G39	Unassigned.
G40	Cancel compensation/offset.
G41	Cutter compensation left.
G42	Cutter compensation right.
G43	Cutter offset, inside corner.
G44	Cutter offset, outside corner.
G45-G49	Unassigned.
G50-G59	Reserved for adaptive control.
G60-G62	Unassigned.

G-Code	Description
G63	Tapping mode.
G64-G69	Unassigned.
G70	Inch programming.
G71	Metric programming.
G72	Circular interpolation - Clockwise (3 dimensional).
G73	Circular interpolation - Counter-clockwise (3 dimensional).
G74	Cancels circular interpolation.
G75-G79	Unassigned.
G80	Cancels fixed cycle.
G81	Drill cycle.
G82	Drill & dwell cycle.
G83	Peck drill cycle.
G84	Tapping cycle.
G85	Boring cycle - rotating spindle retraction.
G86	Boring cycle - rapid traverse.
G87	Boring cycle - manual retraction.
G88	Boring cycle - dwell & manual retraction.
G89	Boring cycle - dwell and feed retraction.
G90	Absolute input programming.
G91	Incremental input programming.
G92	Preload of registers.
G93	Inverse time feed rate.
G94	Feed rate in inches or millimetres per minute.
G95	Feed rate given directly in inches or millimetres per revolution.
G96	Constant surface retraction speed.
G97	Spindle speed programmed in rpm.
G98-99	Unassigned.

LETTER ADDRESSES USED IN NUMERICAL CONTROL

Letter Address	Description	Refers to
A	Angular dimension about the X-axis, measured in decimal parts of a degree	Axis nomenclature
B	Angular dimension about the Y-axis, measured in decimal parts of a degree	Axis nomenclature
C	Angular dimension about the Z-axis, measured in decimal parts of a degree	Axis nomenclature
D	Angular dimension about a special axis, or third feed function, or tool function for selection of tool compensation	Axis nomenclature
E	Angular dimension about a special axis or second feed function	Axis nomenclature
F	Feed word (code)	Feed words
G	Preparatory word (code)	Preparatory words
H	Unassigned	
I	Interpolation parameter or thread lead parallel to the X-axis	Circular interpolation and threading
J	Interpolation parameter or thread lead parallel to the Y-axis	Circular interpolation and threading
K	Interpolation parameter or thread lead parallel to the Z-axis	Circular interpolation and threading
L	Unassigned	
M	Miscellaneous or auxiliary function	Miscellaneous functions
N	Sequence number	Sequence number
O	Sequence number for secondary head only	Sequence number
P	Third rapid-traverse dimension or tertiary-motion dimension parallel to X	Axis nomenclature
Q	Second rapid-traverse dimension or tertiary-motion dimension parallel to Y	Axis nomenclature
R	First rapid-traverse dimension or tertiary-motion dimension parallel to Z or radius for constant surface-speed calculation	Axis nomenclature
S	Spindle-speed function	Spindle-speed
T	Tool function	Tool function
U	Secondary-motion dimension parallel to X	Axis nomenclature
V	Secondary-motion dimension parallel to Y	Axis nomenclature
W	Secondary-motion dimension parallel to Z	Axis nomenclature
X	Primary X-motion dimension	Axis nomenclature
Y	Primary Y-motion dimension	Axis nomenclature
Z	Primary Z-motion dimension	Axis nomenclature

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MISCELLANEOUS FUNCTION WORDS USED IN NUMERICAL CONTROL

Code	Description
M00	Automatically stops the machine. The operator must push a button to continue with the remainder of the program.
M01	An optional stop acted upon only when the operator has previously signaled for this command by pushing a button. On sensing the M01 code, the machine stops automatically.
M02	At the completion of the machining operation, this end-of-program code stops the machine when all commands in the block are executed. May include rewinding the tape.
M03	Starts spindle rotation in a clockwise direction — when viewed from the spindle face.
M04	Starts spindle rotation in a counterclockwise direction — when viewed from the spindle face.
M05	Stops the spindle.
M06	Commands manual or automatic change of tool but does not cover the selection of tool, as is possible with the T-words.
M07	Turns flood coolant on.
M08	Turns mist coolant on.
M09	Turns coolant off.
M10	Applies to auto-clamping of the machine slides, workpiece, fixture spindle, etc.
M11	Unclamping code.
M12	An inhibiting code used to synchronize multiple sets of axes, such as a four-axis lathe having two independently operated heads (turrets).
M13	Simultaneously activates Clockwise spindle motion and coolant flow in the same command.
M14	Simultaneously activates Counterclockwise spindle motion and coolant flow in the same command.
M15 to M16	Rapid traverse of feed motion in either the + (M15) or -(M16) direction.
M17 to M18	Unassigned.
M19	Causes the spindle to stop at a predetermined angular position.
M20 to M29	Permanently unassigned.
M30	An end-of-tape code similar to M02, but M30 will also rewind the tape; also may switch automatically to a second tape reader.
M31	A command known as interlock bypass for temporarily circumventing a normally provided interlock.
M32 to M39	Unassigned.
M40 to M46	Used to signal gear changes if required at the machine; otherwise, unassigned.
M47	Continues program execution from the start of the program unless inhibited by an interlock signal.
M48	Cancels M49.
M49	Deactivates a manual spindle or feed override and returns the parameter to the programmed value.
M50 to M57	Unassigned.
M58	Cancels M59.
M59	Holds the rpm constant at the value in use when M59 is initiated.
M60 to M89	Unassigned.
M90 to M99	Reserved for use by the machine operator.

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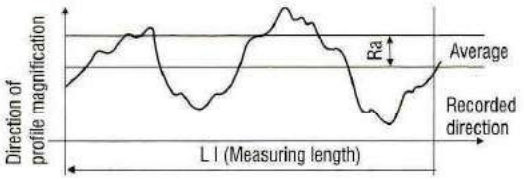
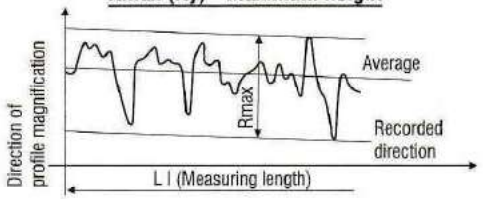
SURFACE ROUGHNESS & CONVERSION TABLES

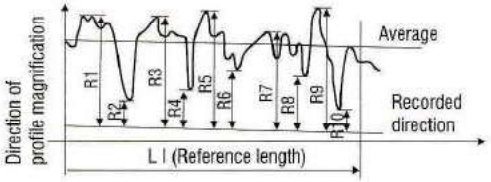
Ra - Average roughness of centerline



Rmax (Ry) - Maximum height



Rz - Average roughness at 10 points



Conversion Tables

Roughness Number	Average Roughness of centerline		Maximum height	Average roughness at 10 points	Triangle Symbol
N	Ra (µm)	Ra (µin)	Ry (µm)	Rz (µm)	▽
N0	0.012	0.50	0.05	0.063	
N1	0.025	1	0.1	0.125	
N2	0.05	2	0.2	0.250	▽▽▽▽
N3	0.10	4	0.4	0.50	
N4	0.20	8	0.8	1.00	
N5	0.40	16	1.6	2.00	
N6	0.80	32	3.2	4.0	▽▽▽
N7	1.6	63	6.3	7.1	
N8	3.2	125	12.5	12.5	▽▽
N9	6.3	250	25	25	
N10	12.5	500	50	50	
N11	25	1000	100	100	▽
N12	50	2000	200	200	

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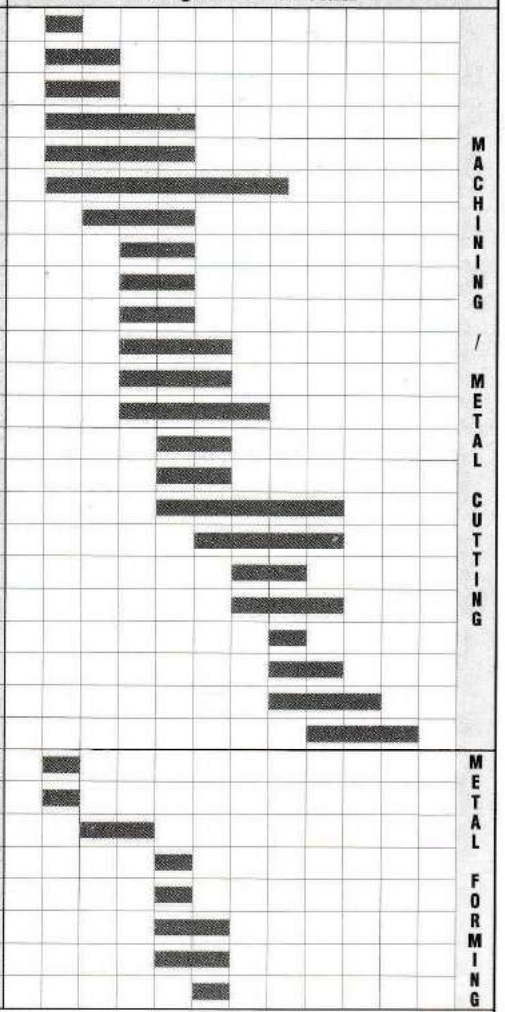
SURFACE FINISH EXPECTED FROM VARIOUS MANUFACTURING PROCESSES

Roughness No.	N12	N11	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1	N0
Micrometers Ra (µm)	50	25	12.5	6.3	3.2	1.6	0.8	0.4	0.2	0.1	0.05	0.025	0.012
Microinches Ra (µin)	2000	1000	500	250	125	63	32	16	8	4	2	1	0.5



NOTE : The ranges shown above are typical for the processes listed. Higher or lower values may be obtained under special conditions.

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COMMON TERMS USED IN THE HEAT TREATMENT OF STEELS

HEAT TREATMENT: A process which involves a combination of heating and cooling of steel in a prescribed manner with respect to time, temperature and rate of heating and cooling so as to induce desired properties in the steel in the solid state.

HARDENING: A process which increases the hardness of steel by changing its chemical and structural makeup.
This usually involves heating the steel to above its critical point and then quenching it in a prescribed medium. Steel with less than 0.3 % carbon cannot be hardened in this manner but its surface can be changed to high carbon steel (by case hardening) which then can be hardened in the normal way.

CASE HARDENING: Hardening the surface layer of steel by changing its composition, followed by heat treatment in the normal manner.
The process of case hardening involves heating the low carbon steel in a rich carbon source (powder or gas) at a specific temperature for a set period of time, whereby carbon is absorbed into the surface of the steel to form a high carbon steel casing. The steel is then hardened and tempered in the normal manner.

QUENCHING: An accelerated cooling process by immersion of the heated steel in liquids or gases.
Oils are often preferred to water as a quenching medium as they are less drastic and more uniform in their cooling effect. Quenching in water produces very hard steel whilst quenching in oil produces a slightly softer steel that is less likely to crack or distort.

TEMPERING: Re-heating the quenched steel to a temperature below the transformation range and, if, necessary, holding at that temperature, followed by cooling at a suitable rate to achieve desired mechanical properties.

CARBURIZING (CASE CARBURIZING): A process of introducing carbon into the surface of a solid piece of steel by heating and holding above the transformation temperature in contact with a suitable carbonaceous medium.

FLAME HARDENING: Rapid heating of the surface layer of the steel by means of a flame to a temperature above the transformation range, followed by immediate quenching.

INDUCTION HARDENING: A process of heating by electrical induction to the appropriate temperature and quenching in a suitable medium.

NITRIDING: A process of surface hardening by introducing Nitrogen into the surface in a suitable steel by heating and holding it at an appropriate temperature in contact with cracked ammonia or other suitable nitrogenous medium.
This process produces a hard case in the steel without further need for heat treatment.

NORMALISING: A process of heat treatment for improving mechanical properties brought about by grain refinement and uniformity in structure. The process involves heating and holding for a specified time at a suitable temperature above the transformation range, followed by cooling freely in air.

STRESS RELIEVING (STABILIZING): Heating to and if necessary, holding at a sufficiently high temperature below the transformation range, followed by slow cooling to remove internal stresses only.

STEEL HARDENING/TEMPERING TEMPERATURES JUDGED BY COLOUR

Deg. C	Deg. F	Colour	
1400	2552	White welding heat	HARDENING
1300	2372	Yellow-White	
1200	2192	Orange-Yellow	
1100	2012	Orange-Red	
1000	1832	Bright Cherry-Red	
900	1652	Cherry-Red	
800	1472	Dull Cherry-Red	
700	1292	Dark Red	
581	1077	Red heat, visible in sunlight	
525	975	Red heat, visible in daylight	
330	626	Greyish Green	TEMPERING
320	608	Grey	
310	590	Light Blue	
299	570	Dark Blue	
293	560	Full Blue	
288	550	Dark Purple	
282	540	Full Purple	
277	530	Light Purple	
271	520	Brown Purple	
266	510	Spotted-Brown	
260	500	Brown Yellow	
254	490	Yellow Brown	
249	480	Dark Yellow	
243	470	Deep Straw Yellow	
238	460	Straw Yellow	
232	450	Pale Straw Yellow	
227	440	Light Yellow	
221	430	Very Pale Yellow	

Note: The above colours are intended as a guide only and should not be assumed to be an accurate temperature indicator. Colours vary according to metal composition.

HARDNESS COMPARISON CHART

Brinell Hardness (HB) 3,000 kg	Rockwell Hardness				Vickers Hardness 50 kg	Shore Hardness	Transverse Rupture Strength (kg/mm²)
	HRA Scale 60 kg Brale	HRB Scale 100 kg 1/16 in Ball	HRC Scale 150 kg Brale	HRD Scale 100 kg Brale			
--	85.6	--	68.0	76.9	940	97	--
--	85.3	--	67.5	76.5	920	96	--
--	85.0	--	67.0	76.1	900	95	--
767	84.7	--	66.4	75.7	880	93	--
757	84.4	--	65.9	75.3	860	92	--
745	84.1	--	65.3	74.8	840	91	--
733	83.8	--	64.7	74.3	820	90	--
722	83.4	--	64.0	73.8	800	88	--
712	--	--	--	--	--	--	--
710	83.0	--	63.3	73.3	780	87	--
698	82.6	--	62.5	72.6	760	86	--
684	82.2	--	61.8	72.1	740	--	--
682	82.2	--	61.7	72.0	737	84	--
670	81.8	--	61.0	71.5	720	83	--
656	81.3	--	60.1	70.8	700	--	--
653	81.2	--	60.0	70.7	697	81	--
647	81.1	--	59.7	70.5	690	--	--
638	80.8	--	59.2	70.1	680	80	--
630	80.6	--	58.8	69.8	670	--	--
627	80.5	--	58.7	69.7	667	79	--
601	79.8	--	57.3	68.7	640	77	--
578	79.1	--	56.0	67.7	615	75	--
555	78.4	--	54.7	66.7	591	73	210
534	77.8	--	53.5	65.8	569	71	202
514	76.9	--	52.1	64.7	547	70	193
495	76.3	--	51.0	63.8	528	68	186
477	75.6	--	49.6	62.7	508	66	177
461	74.9	--	48.5	61.7	491	65	170
444	74.2	--	47.1	60.8	472	63	162
429	73.4	--	45.7	59.7	455	61	154
415	72.8	--	44.5	58.8	440	59	149
401	72.0	--	43.1	57.8	425	58	142
388	71.4	--	41.8	56.8	410	56	136
375	70.6	--	40.4	55.7	396	54	129
363	70.0	--	39.1	54.6	383	52	124
352	69.3	(110.0)	37.9	53.8	372	51	120
341	68.7	(109.0)	36.6	52.8	360	50	115
331	68.1	(108.5)	35.5	51.9	350	48	112

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HARDNESS COMPARISON CHART

Brinell Hardness (HB) 3,000 kg	Rockwell Hardness				Vickers Hardness 50 kg	Shore Hardness	Transverse Rupture Strength (kg/mm²)
	HRA Scale 60 kg Brale	HRB Scale 100 kg 1/16 in Ball	HRC Scale 150 kg Brale	HRD Scale 100 kg Brale			
321	67.5	(108.0)	34.3	51.0	339	47	108
311	66.9	(107.5)	33.1	50.0	328	46	105
302	66.3	(107.0)	32.1	49.3	319	45	103
293	65.7	(106.0)	30.9	48.3	309	43	99
285	65.3	(105.5)	29.9	47.6	301	--	97
277	64.6	(104.5)	28.8	46.7	292	41	94
269	64.1	(104.0)	27.6	45.9	284	40	91
262	63.6	(103.0)	26.6	45.0	276	39	89
255	63.0	(102.0)	25.4	44.2	269	38	86
248	62.5	(101.0)	24.2	43.2	261	37	84
241	61.8	100.0	22.8	42.0	253	36	82
235	61.4	99.0	21.7	41.4	247	35	80
229	60.8	98.2	20.5	40.5	241	34	78
223	--	97.3	(18.8)	--	234	--	--
217	--	96.4	(17.5)	--	228	33	74
212	--	95.5	(16.0)	--	222	--	72
207	--	94.6	(15.2)	--	218	32	70
201	--	93.8	(13.8)	--	212	31	69
197	--	92.8	(12.7)	--	207	30	67
192	--	91.9	(11.5)	--	202	29	65
187	--	90.7	(10.0)	--	196	--	63
183	--	90.0	(9.0)	--	192	28	63
179	--	89.0	(8.0)	--	188	27	61
174	--	87.8	(6.4)	--	182	--	60
170	--	86.8	(5.4)	--	178	26	58
167	--	86.0	(4.4)	--	175	--	57
163	--	85.0	(3.3)	--	171	25	56
156	--	82.9	(0.9)	--	163	--	53
149	--	80.8	--	--	156	23	51
143	--	78.7	--	--	150	22	50
137	--	76.4	--	--	143	21	47
131	--	74.0	--	--	137	--	46
126	--	72.0	--	--	132	20	44
121	--	69.8	--	--	127	19	42
116	--	67.6	--	--	122	18	41
111	--	65.7	--	--	117	15	39

1) In above chart, figures with ( ) are not commonly used.
2) Rockwell scale A, C and D are scaled with diamond brale.

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TABLE OF NATURAL SINES

SINE

Deg.	0	10	20	30	40	50	60	
0	.00000	.00291	.00582	.00873	.01164	.01454	.01745	89
1	.01745	.02036	.02327	.02618	.02908	.03199	.03490	88
2	.03490	.03781	.04071	.04362	.04653	.04943	.05234	87
3	.05234	.05524	.05814	.06105	.06395	.06685	.06976	86
4	.06976	.07266	.07556	.07846	.08136	.08426	.08716	85
5	.08716	.09005	.09295	.09585	.09874	.10164	.10453	84
6	.10453	.10742	.11031	.11320	.11609	.11898	.12187	83
7	.12187	.12476	.12764	.13053	.13341	.13629	.13917	82
8	.13917	.14205	.14493	.14781	.15069	.15356	.15643	81
9	.15643	.15931	.16218	.16505	.16792	.17078	.17365	80
10	.17365	.17651	.17937	.18224	.18509	.18795	.19081	79
11	.19081	.19366	.19652	.19937	.20222	.20507	.20791	78
12	.20791	.21076	.21360	.21644	.21928	.22212	.22495	77
13	.22495	.22778	.23062	.23345	.23627	.23910	.24192	76
14	.24192	.24474	.24756	.25038	.25320	.25601	.25882	75
15	.25882	.26163	.26443	.26724	.27004	.27284	.27564	74
16	.27564	.27843	.28123	.28402	.28680	.28959	.29237	73
17	.29237	.29515	.29793	.30071	.30348	.30625	.30902	72
18	.30902	.31178	.31454	.31730	.32006	.32282	.32557	71
19	.32557	.32832	.33106	.33381	.33655	.33929	.34202	70
20	.34202	.34475	.34748	.35021	.35293	.35565	.35837	69
21	.35837	.36108	.36379	.36650	.36921	.37191	.37461	68
22	.37461	.37730	.37999	.38268	.38537	.38805	.39073	67
23	.39073	.39341	.39608	.39875	.40141	.40408	.40674	66
24	.40674	.40939	.41204	.41469	.41734	.41998	.42262	65
25	.42262	.42525	.42788	.43051	.43313	.43575	.43837	64
26	.43837	.44098	.44359	.44620	.44880	.45140	.45399	63
27	.45399	.45658	.45917	.46175	.46433	.46690	.46947	62
28	.46947	.47204	.47460	.47716	.47971	.48226	.48481	61
29	.48481	.48735	.48989	.49242	.49495	.49748	.50000	60
30	.50000	.50252	.50503	.50754	.51004	.51254	.51504	59
31	.51504	.51753	.52002	.52250	.52498	.52745	.52992	58
32	.52992	.53238	.53484	.53730	.53975	.54220	.54464	57
33	.54464	.54708	.54951	.55194	.55436	.55678	.55919	56
34	.55919	.56160	.56401	.56641	.56880	.57119	.57358	55
35	.57358	.57596	.57833	.58070	.58307	.58543	.58779	54
36	.58779	.59014	.59248	.59482	.59716	.59949	.60182	53
37	.60182	.60414	.60645	.60876	.61107	.61337	.61566	52
38	.61566	.61795	.62024	.62251	.62479	.62706	.62932	51
39	.62932	.63158	.63383	.63608	.63832	.64056	.64279	50
40	.64279	.64501	.64723	.64945	.65166	.65386	.65606	49
41	.65606	.65825	.66044	.66262	.66480	.66697	.66913	48
42	.66913	.67129	.67344	.67559	.67773	.67987	.68200	47
43	.68200	.68412	.68624	.68835	.69046	.69256	.69466	46
44	.69466	.69675	.69883	.70091	.70298	.70505	.70711	45
	60	50	40	30	20	10	0	Deg

COSINE

TABLE OF NATURAL SINES

SINE

Deg	0	10	20	30	40	50	60	
45	.70711	.70916	.71121	.71325	.71529	.71732	.71934	44
46	.71934	.72136	.72337	.72537	.72737	.72937	.73135	43
47	.73135	.73333	.73531	.73728	.73924	.74120	.74314	42
48	.74314	.74509	.74703	.74896	.75088	.75280	.75471	41
49	.75471	.75661	.75851	.76041	.76229	.76417	.76604	40
50	.76604	.76791	.76977	.77162	.77347	.77531	.77715	39
51	.77715	.77897	.78079	.78261	.78442	.78622	.78801	38
52	.78801	.78980	.79158	.79335	.79512	.79688	.79864	37
53	.79864	.80038	.80212	.80386	.80558	.80730	.80902	36
54	.80902	.81072	.81242	.81412	.81580	.81748	.81915	35
55	.81915	.82082	.82248	.82413	.82577	.82741	.82904	34
56	.82904	.83066	.83228	.83389	.83549	.83708	.83867	33
57	.83867	.84025	.84182	.84339	.84495	.84650	.84805	32
58	.84805	.84959	.85112	.85264	.85416	.85567	.85717	31
59	.85717	.85866	.86015	.86163	.86310	.86457	.86603	30
60	.86603	.86748	.86892	.87036	.87178	.87321	.87462	29
61	.87462	.87603	.87743	.87882	.88020	.88158	.88295	28
62	.88295	.88431	.88566	.88701	.88835	.88968	.89101	27
63	.89101	.89232	.89363	.89493	.89623	.89752	.89879	26
64	.89879	.90007	.90133	.90259	.90383	.90507	.90631	25
65	.90631	.90753	.90875	.90996	.91116	.91236	.91355	24
66	.91355	.91472	.91590	.91706	.91822	.91936	.92050	23
67	.92050	.92164	.92276	.92388	.92499	.92609	.92718	22
68	.92718	.92827	.92935	.93042	.93148	.93253	.93358	21
69	.93358	.93462	.93565	.93667	.93769	.93869	.93969	20
70	.93969	.94068	.94167	.94264	.94361	.94457	.94552	19
71	.94552	.94646	.94740	.94832	.94924	.95015	.95106	18
72	.95106	.95195	.95284	.95372	.95459	.95545	.95630	17
73	.95630	.95715	.95799	.95882	.95964	.96046	.96126	16
74	.96126	.96206	.96285	.96363	.96440	.96517	.96593	15
75	.96593	.96667	.96742	.96815	.96887	.96959	.97030	14
76	.97030	.97100	.97169	.97237	.97304	.97371	.97437	13
77	.97437	.97502	.97566	.97630	.97692	.97754	.97815	12
78	.97815	.97875	.97934	.97992	.98050	.98107	.98163	11
79	.98163	.98218	.98272	.98325	.98378	.98430	.98481	10
80	.98481	.98531	.98580	.98629	.98676	.98723	.98769	9
81	.98769	.98814	.98858	.98902	.98944	.98986	.99027	8
82	.99027	.99067	.99106	.99144	.99182	.99219	.99255	7
83	.99255	.99290	.99324	.99357	.99390	.99421	.99452	6
84	.99452	.99482	.99511	.99540	.99567	.99594	.99619	5
85	.99619	.99644	.99668	.99692	.99714	.99736	.99756	4
86	.99756	.99776	.99795	.99813	.99831	.99847	.99863	3
87	.99863	.99878	.99892	.99905	.99917	.99929	.99939	2
88	.99939	.99949	.99958	.99966	.99973	.99979	.99985	1
89	.99985	.99989	.99993	.99996	.99998	.99999	1.00000	0
	60	50	40	30	20	10	0	Deg

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0	.00000	.00291	.00582	.00873	.01164	.01455	.01746	89
1	.01746	.02036	.02328	.02619	.02910	.03201	.03492	88
2	.03492	.03783	.04075	.04366	.04658	.04949	.05241	87
3	.05241	.05533	.05824	.06116	.06408	.06700	.06993	86
4	.06993	.07285	.07578	.07870	.08163	.08456	.08749	85
5	.08749	.09042	.09335	.09629	.09923	.10216	.10510	84
6	.10510	.10805	.11099	.11394	.11688	.11983	.12278	83
7	.12278	.12574	.12869	.13165	.13461	.13758	.14054	82
8	.14054	.14351	.14648	.14945	.15243	.15540	.15838	81
9	.15838	.16137	.16435	.16734	.17033	.17333	.17633	80
10	.17633	.17933	.18233	.18534	.18835	.19136	.19438	79
11	.19438	.19740	.20042	.20345	.20648	.20952	.21256	78
12	.21256	.21560	.21864	.22169	.22475	.22781	.23087	77
13	.23087	.23393	.23700	.24008	.24316	.24624	.24933	76
14	.24933	.25242	.25552	.25862	.26172	.26483	.26795	75
15	.26795	.27107	.27419	.27732	.28046	.28360	.28675	74
16	.28675	.28990	.29305	.29621	.29938	.30255	.30573	73
17	.30573	.30891	.31210	.31530	.31850	.32171	.32492	72
18	.32492	.32814	.33136	.33460	.33783	.34108	.34433	71
19	.34433	.34758	.35085	.35412	.35740	.36068	.36397	70
20	.36397	.36727	.37057	.37388	.37720	.38053	.38386	69
21	.38386	.38721	.39055	.39391	.39727	.40065	.40403	68
22	.40403	.40741	.41081	.41421	.41763	.42105	.42447	67
23	.42447	.42791	.43136	.43481	.43828	.44175	.44523	66
24	.44523	.44872	.45222	.45573	.45924	.46277	.46631	65
25	.46631	.46985	.47341	.47698	.48055	.48414	.48773	64
26	.48773	.49134	.49495	.49858	.50222	.50587	.50953	63
27	.50953	.51319	.51688	.52057	.52427	.52798	.53171	62
28	.53171	.53545	.53920	.54296	.54673	.55051	.55431	61
29	.55431	.55812	.56194	.56577	.56962	.57348	.57735	60
30	.57735	.58124	.58513	.58905	.59297	.59691	.60086	59
31	.60086	.60483	.60881	.61280	.61681	.62083	.62487	58
32	.62487	.62892	.63299	.63707	.64117	.64528	.64941	57
33	.64941	.65355	.65771	.66189	.66608	.67028	.67451	56
34	.67451	.67875	.68301	.68728	.69157	.69588	.70021	55
35	.70021	.70455	.70891	.71329	.71769	.72211	.72654	54
36	.72654	.73100	.73547	.73996	.74447	.74900	.75355	53
37	.75355	.75812	.76272	.76733	.77196	.77661	.78129	52
38	.78129	.78598	.79070	.79544	.80020	.80498	.80978	51
39	.80978	.81461	.81946	.82434	.82923	.83415	.83910	50
40	.83910	.84407	.84906	.85408	.85912	.86419	.86929	49
41	.86929	.87441	.87955	.88473	.88992	.89515	.90040	48
42	.90040	.90569	.91099	.91633	.92170	.92709	.93252	47
43	.93252	.93797	.94345	.94896	.95451	.96008	.96569	46
44	.96569	.97133	.97700	.98270	.98843	.99420	1.00000	45
	60	50	40	30	20	10	0	Deg

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45	1.00000	1.00583	1.01170	1.01761	1.02355	1.02952	1.03553	44
46	1.03553	1.04158	1.04766	1.05378	1.05994	1.06613	1.07237	43
47	1.07237	1.07864	1.08496	1.09131	1.09770	1.10414	1.11061	42
48	1.11061	1.11713	1.12369	1.13029	1.13694	1.14363	1.15037	41
49	1.15037	1.15715	1.16398	1.17085	1.17777	1.18474	1.19175	40
50	1.19175	1.19882	1.20593	1.21310	1.22031	1.22758	1.23490	39
51	1.23490	1.24227	1.24969	1.25717	1.26471	1.27230	1.27994	38
52	1.27994	1.28764	1.29541	1.30323	1.31110	1.31904	1.32704	37
53	1.32704	1.33511	1.34323	1.35142	1.35968	1.36800	1.37638	36
54	1.37638	1.38484	1.39336	1.40195	1.41061	1.41934	1.42815	35
55	1.42815	1.43703	1.44598	1.45501	1.46411	1.47330	1.48256	34
56	1.48256	1.49190	1.50133	1.51084	1.52043	1.53010	1.53986	33
57	1.53986	1.54972	1.55966	1.56969	1.57981	1.59002	1.60033	32
58	1.60033	1.61074	1.62125	1.63185	1.64256	1.65337	1.66428	31
59	1.66428	1.67530	1.68643	1.69766	1.70901	1.72047	1.73205	30
60	1.73205	1.74375	1.75556	1.76749	1.77955	1.79174	1.80405	29
61	1.80405	1.81649	1.82906	1.84177	1.85462	1.86760	1.88073	28
62	1.88073	1.89400	1.90741	1.92098	1.93470	1.94858	1.96261	27
63	1.96261	1.97681	1.99116	2.00569	2.02039	2.03526	2.05030	26
64	2.05030	2.06553	2.08094	2.09654	2.11233	2.12832	2.14451	25
65	2.14451	2.16090	2.17749	2.19430	2.21132	2.22857	2.24604	24
66	2.24604	2.26374	2.28167	2.29984	2.31826	2.33693	2.35585	23
67	2.35585	2.37504	2.39449	2.41421	2.43422	2.45451	2.47509	22
68	2.47509	2.49597	2.51715	2.53865	2.56046	2.58261	2.60509	21
69	2.60509	2.62791	2.65109	2.67462	2.69853	2.72281	2.74748	20
70	2.74748	2.77254	2.79802	2.82391	2.85023	2.87700	2.90421	19
71	2.90421	2.93189	2.96004	2.98868	3.01783	3.04749	3.07768	18
72	3.07768	3.10842	3.13972	3.17159	3.20406	3.23714	3.27085	17
73	3.27085	3.30521	3.34023	3.37594	3.41236	3.44951	3.48741	16
74	3.48741	3.52609	3.56557	3.60588	3.64705	3.68909	3.73205	15
75	3.73205	3.77595	3.82083	3.86671	3.91364	3.96165	4.01078	14
76	4.01078	4.06107	4.11256	4.16530	4.21933	4.27471	4.33148	13
77	4.33148	4.38969	4.44942	4.51071	4.57363	4.63825	4.70463	12
78	4.70463	4.77286	4.84300	4.91516	4.98940	5.06584	5.14455	11
79	5.14455	5.22566	5.30928	5.39552	5.48451	5.57638	5.67128	10
80	5.67128	5.76937	5.87080	5.97576	6.08444	6.19703	6.31375	9
81	6.31375	6.43484	6.56055	6.69116	6.82694	6.96823	7.11537	8
82	7.11537	7.26873	7.42871	7.59575	7.77035	7.95302	8.14435	7
83	8.14435	8.34496	8.55555	8.77689	9.00983	9.25530	9.51436	6
84	9.51436	9.78817	10.07803	10.38540	10.71191	11.05943	11.43005	5
85	11.43005	11.82617	12.25051	12.70620	13.19688	13.72674	14.30067	4
86	14.30067	14.92442	15.60478	16.34986	17.16934	18.07498	19.08114	3
87	19.08114	20.20555	21.47040	22.90377	24.54176	26.43160	28.63625	2
88	28.63625	31.24158	34.36777	38.18846	42.96408	49.10388	57.28996	1
89	57.28996	68.75009	85.93979	114.58865	171.88540	343.77371	Infinity	0
	60	50	40	30	20	10	0	Deg

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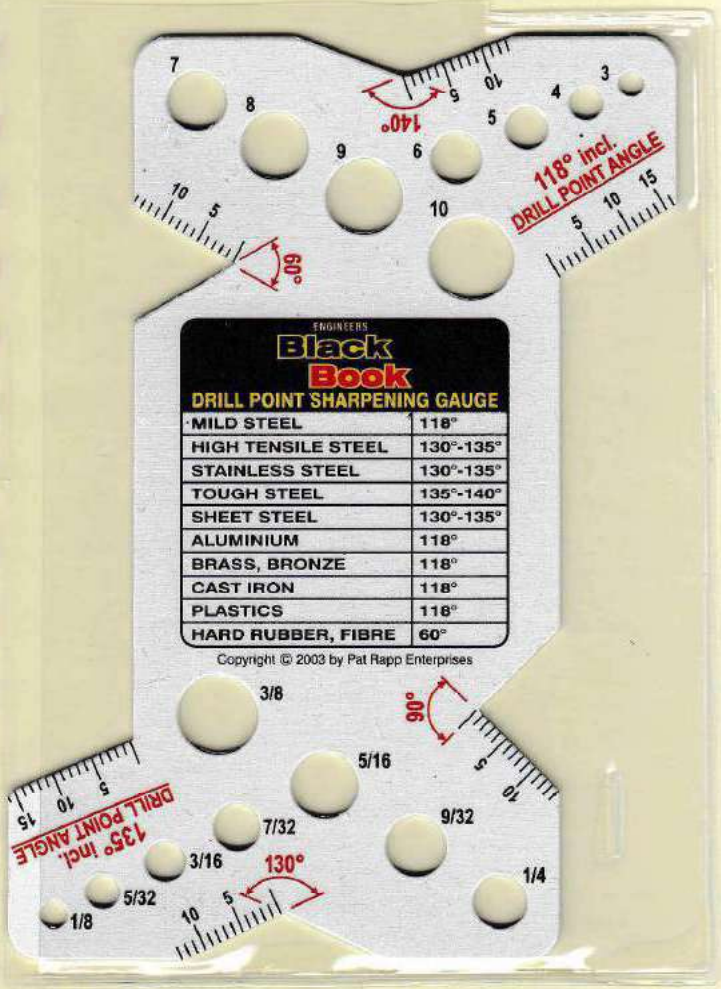
(Refer Pages 40, 41 & 42)